Waste-to-Energy Options and Solid Waste Export Considerations

Presentation to King County

November 6, 2017

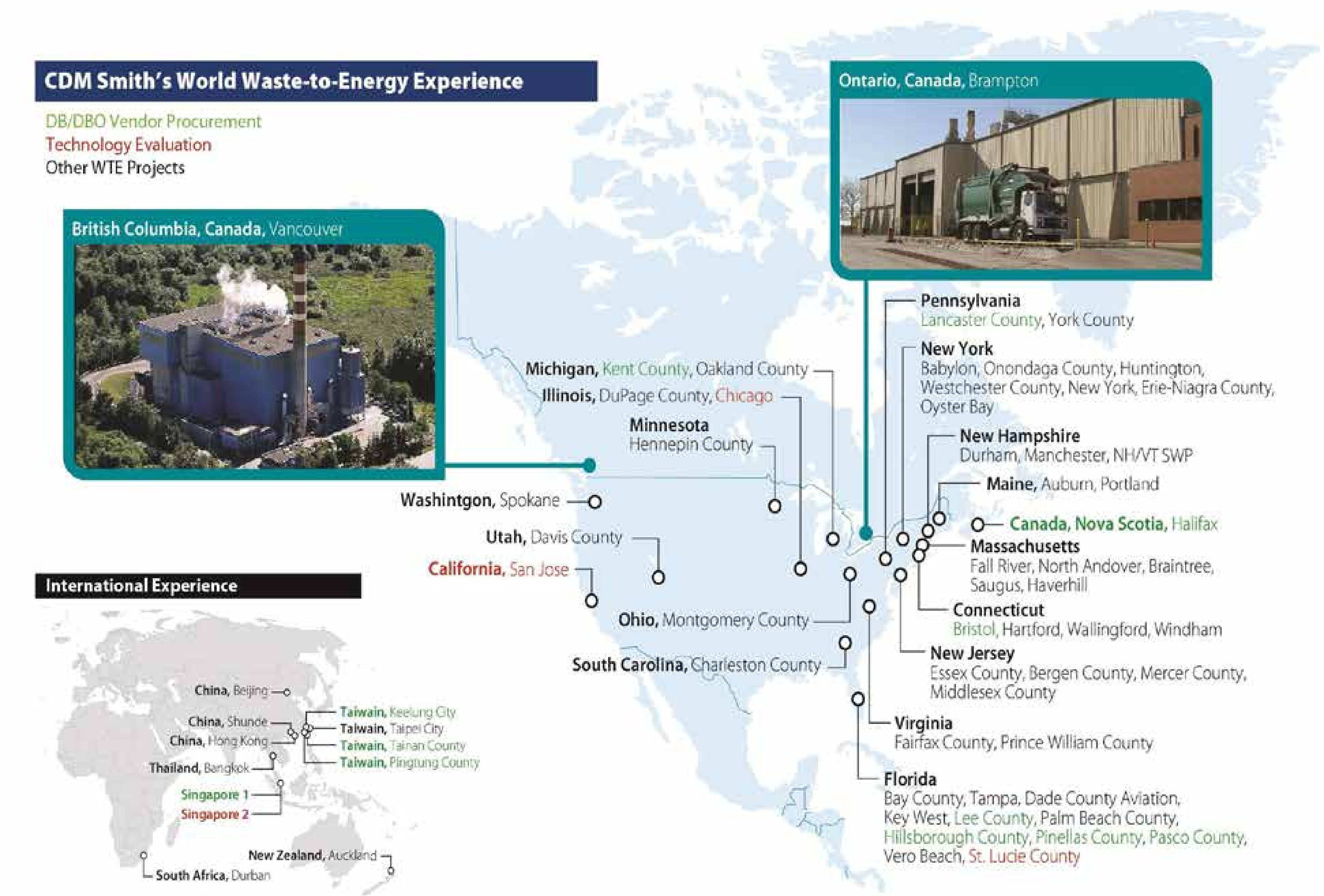
Agenda

- Introduction
- King County Solid Waste Existing Conditions
- Best Fit WTE Option
- Financial Analysis
- Solid Waste Export Considerations
- Recommendations
- Next Steps

Task 3 Presentation
WTE Existing Conditions, Best Fit WTE Option and Financial Analysis

Sustainable Waste Management Solutions for the 21st Century

Paul Hauck, P.E.
CDM Smith
November 2017


CDM Smith's World Waste-to-Energy Experience
DB/DBO Vendor Procurement
Technology Evaluation
Other WTE Projects
British Columbia, Canada, Vancouver
Ontario, Canada, Brampton
Pennsylvania
Lancaster County, York County
New York
Babylon, Onondaga County, Huntington, Westchester County, New York, Erie-Niagra County, Oyster Bay
New Hampshire
Durham, Manchester, NH/VT SWP
Maine, Auburn, Portland
Canada, Nova Scotia, Halifax
Massachusetts
Fall River, North Andover, Braintree, Saugus, Haverhill
Connecticut
Bristol, Hartford, Wallingford, Windham
New Jersey
Essex County, Bergen County, Mercer County, Middlesex County
Virginia
Fairfax County, Prince William County
Florida
Bay County, Tampa, Dade County Aviation, Key West, Lee County, Palm Beach County, Hillsborough County, Pinellas County, Pasco County, Vero Beach, St. Lucie County
Michigan, Kent County, Oakland County
Illinois, DuPage County, Chicago
Minnesota
Hennepin County
Washintgon, Spokane
Utah, Davis County
California, San Jose
Ohio, Montgomery County
South Carolina, Charleston County
International Experience
China, Beijing
China, Shunde
China, Hong Kong
Thailand, Bangkok
Singapore 1
Singapore 2
Taiwain, Keelung City
Taiwain, Taipei City
Taiwain, Tainan County
Taiwain, Pingtung County
New Zealand, Auckland
South Africa, Durban

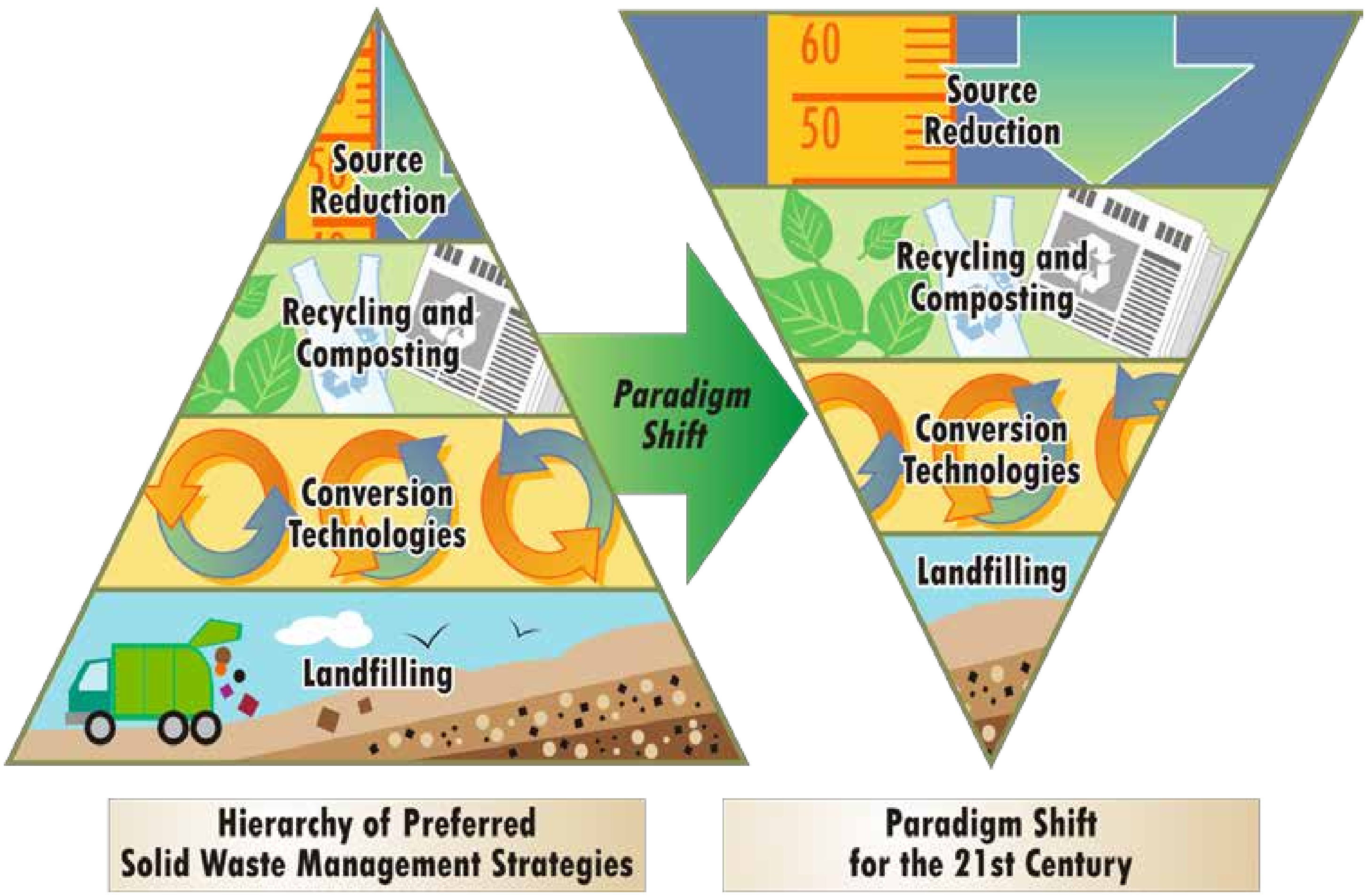
My Career in Solid Waste and Waste-to-Energy

Consulting Engineer
WTE Facility Operations
1996 - Present

U.S. and European Waste Management Hierarchy are in Close Agreement

- Waste Prevention
- Re-use
- Recycling
- Maximize Recovery of Energy and Materials
- Minimize Landfill Waste Disposal

No Matter How You Look at it, WTE Occupies the Third Step of the Waste Management Hierarchy



Evolution of WTE Technology

Element	Incineration	1st Generation WTE	2nd Generation Modern WTE	3rd Generation Advanced RR
Year	1910-1970	1970-1985	1985-1995	2011-2017
Aesthetics	Industrial	Industrial	Enhanced	Enhanced Plus
Steam Conditions	None	600 psi	835/ 1350 psi	850 / 1400 psi
Net Electrical Generation	0	475	570/ 725	575-600/ 750
Combustion Control	Basic	Computer Based	Advanced	Optimized
Air Pollution Control	None	Electrostatic Precipitators	Scrubber / Fabric Filters with Activated Carbon	Scrubber / Fabric Filters with Activated Carbon, Very Low NOx
Ferrous Recovery	None	Electromagnets 2.0 – 2.5%	Permanent Magnets 2.5%	Rare Earth Magnets 3.5% +
Non-ferrous Recovery	None	None	Eddy Current Separators (ECS)	High Strength ECS (90% recovery)
Beneficial Reuse of Ash Residue	None	None	Within Landfill Campus	Multiple Uses

Modern WTE Trends...Improved Efficiency and Sustainability, Yet Lower Power Payments!

Increasing Trends

- Advanced ferrous and non-ferrous metal recovery
- Advanced combustion controls
- Higher boiler/TG availability and gross/net electric generation
- Use of reclaimed water for cooling
- Higher Heating Value (HHV) of MSW
- Compliance with stringent emission limits & GHG reporting
- WTE facility expansions and attention to aesthetics/LEED®/innovation
- Evolution of integrated solid waste management/eco-campus

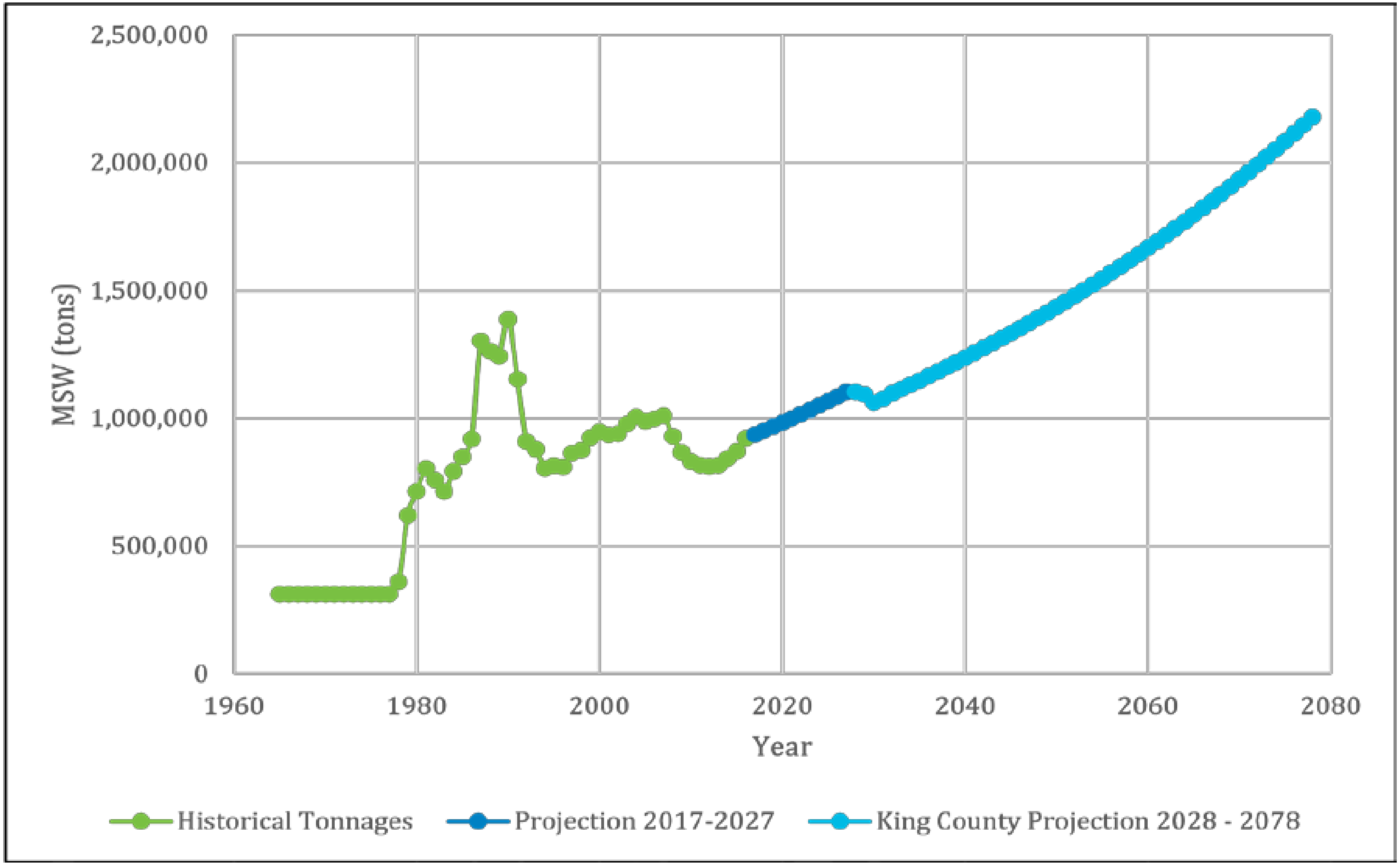
Trends Decreasing

- Air pollution emissions
- Chemical reagent consumption
- Water consumption
- Lower payments for electricity sold to electric grid

Benefits of WTE to Regional Electrical Grid Reliability and Resiliency

- Centrally located distributed energy
  - Typically located in close proximity to urban electrical demand
  - Distributed source of generation, with minimal line losses
- Reliable base load source of renewable energy
  - Supports proper operating voltages on local electrical grid
- Delays need to permit and construct new units as aging and uneconomical fossil units are retired
- Improves "fuel" diversity to local electrical grid for reliability during interruptions in fuel or hydro water supply (pending legislation by DOE for power plants with 90 day fuel supplies)
- Compatible with Microgrid Concept
  - Improves resiliency of critical municipal infrastructure (power, water, wastewater, public works, emergency and disaster management, etc.)

King County's Estimated Waste Projection (assumes 57% recycling rate from 2018 - 2078)



Waste Conversion Technology Evaluation Criteria

- State of technology (15 points)
- Technical performance (10 points)
- Technical resources (5 points)
- Facility siting and public acceptance (5 points)
- Environmental criteria (15 points)
- Environmental criteria – sustainability (10 points)
- Financial resources (10 points)
- Project economics (20 points)
- Overall project risks (10 points)

Highest Ranked Proven Technology Determined to be Combustion on Movable Grates with Waterwall Boilers

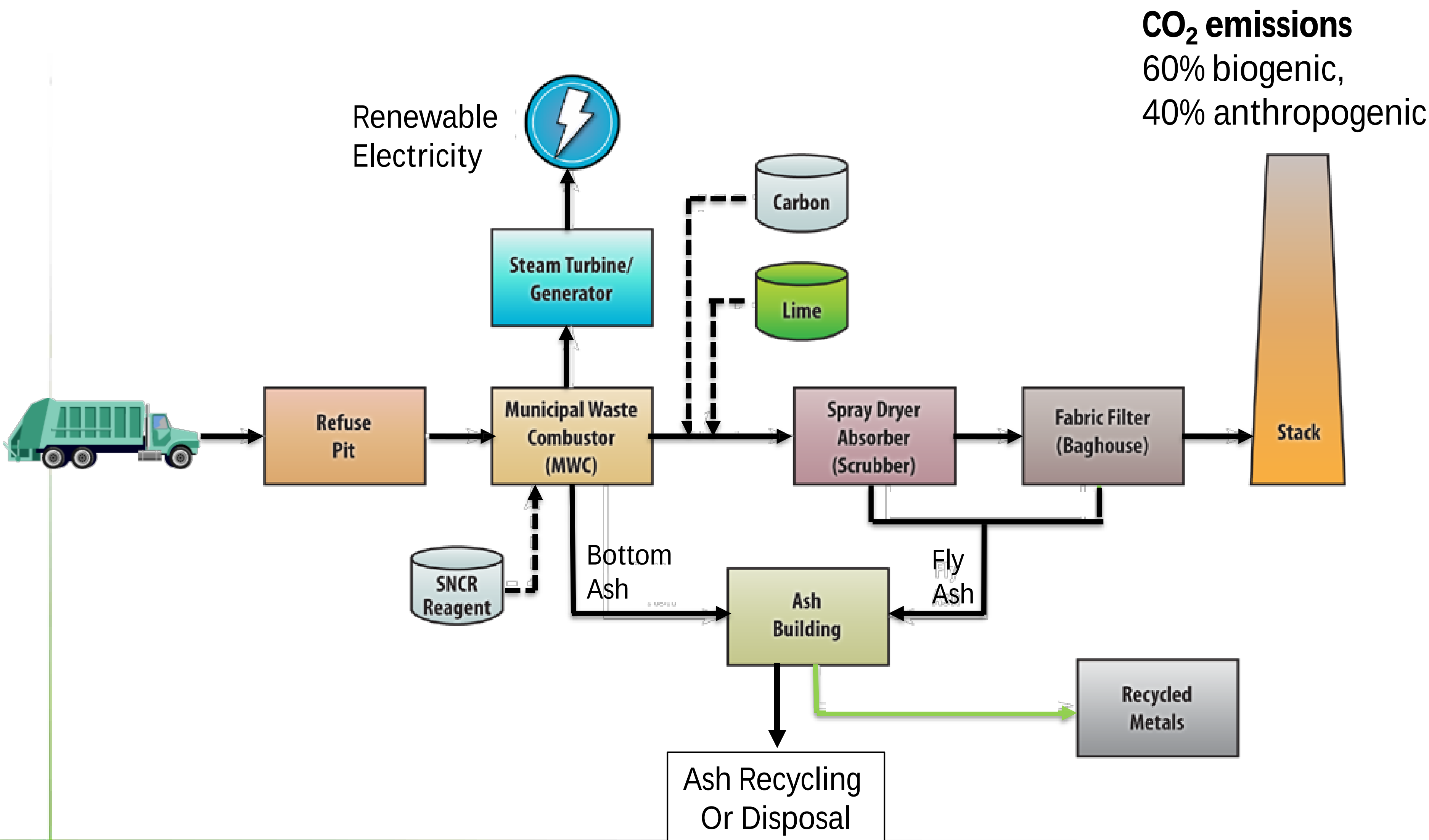
Criteria Number	Criteria Description (Major / Minor)	Possible Points	Massburn	RDF WTE	ATR	Waste Conversion Technology Thermal Gasification	Plasma Arc Gasification	Biochemical Biofuels	Thermochemical Biofuels	RDF to Kiln
1.0	State of Technology	15	15	15	15	5	3	5	3	12
	Degree to which entire system has been proven on a commercial scale in the U.S.									
	Operating history / Availability									
	Freedom from high risk failure modes									
	Demonstrated reliability of entire system									
2.0	Technical Performance	10	9	7	9	4	4	4	5	7
	Compatibility with full spectrum of waste processing needs									
	Ability to produce marketable byproducts									
	Need for pre-processing									
3.0	Technical Resources	5	5	4	5	1	1	1	1	3
	Proven contractor experience in waste processing									
	Proximity of technical support									
	Availability to provide support on continuing basis									
4.0	Facility Siting and Public Acceptance	5	4	4	4	4	4	3	3	5
	Acceptable site									
	Synergy with adjacent activities									
	Adequate utilities									
	Adequate / affordable electric interconnection									
	Synergy with local infrastructure									
	Public acceptance									
	Local economic impacts									
5.0	Environmental Criteria	15	15	12	15	5	5	4	4	12
	Data to support ability of control technology for air emissions									
	Data to support ability of control technology for solid emissions									
	Data to support ability of control technology for water emissions									
	Data to support ability of control technology for odor emissions									
	Data to support ability of control technology for noise emissions									
	Reduction in greenhouse gasses									
6.0	Environmental Criteria - Sustainability	10	8	8	9	7	7	9	7	8
	Impacts on local resources									
	Impacts on neighboring communities									
	Impacts on natural habitats									
	Compatibility with local environmental goals									
	Compatibility with local waste reduction goals									
	Synergistic with municipal utilities and recycling processes									
7.0	Financial Resources	10	10	10	10	3	3	3	3	8
	Ability of vendor to finance project without public money									
	Ability to endure and achieve performance goals during prolonged startup and testing phases									
	Ability to make municipality whole from their investments and costs if technology fails									
	Financial reserves in escrow to dismantle and remove in event of failure									
8.0	Project Economics	20	20	18	20	10	7	7	7	10
	Requirement for Public capital investment									
	Commitment for delivery of wastes									
	Acceptable contract terms and conditions									
	Economic benefits to the community									
	Realistic estimate of project revenues / incomes									
	Realistic assumptions for estimation of operation and maintenance expenses									
	Costs to commercial, industrial, or institutions									
9.0	Overall Project Risks	10	9	7	8	3	3	3	5	7
	Economic realities									
	Technical risk									
	Procurement issues									
	Fatal flaws									
	Contractual risk									
	Contract terms									
	Total Score	100	95	85	95	42	37	39	38	72

Total Score:	95	85	95	42	37	39	38	72

B&W Volund Dynagrate™ Employs Special Alloy Steel with Expert Combustion Controls

Credit: B&W Volund

Typical Combustion WTE Flow Diagram



Typical Combustion WTE Facility Cross-Section

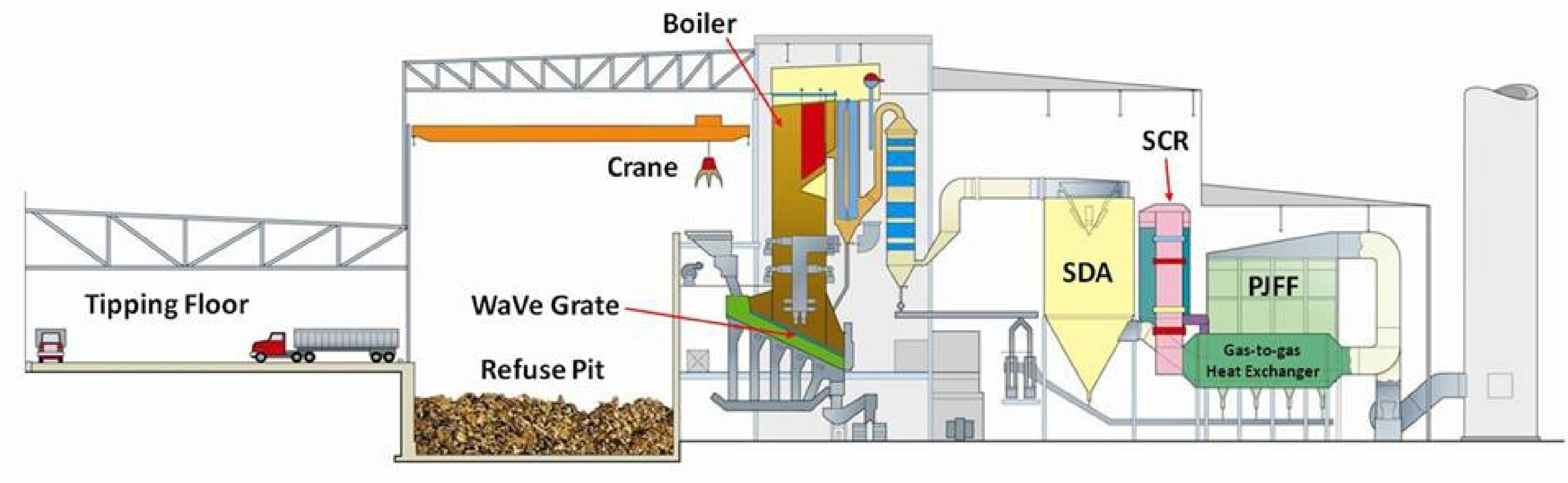


Illustration of B&W Volund technology employed in Palm Beach County Florida

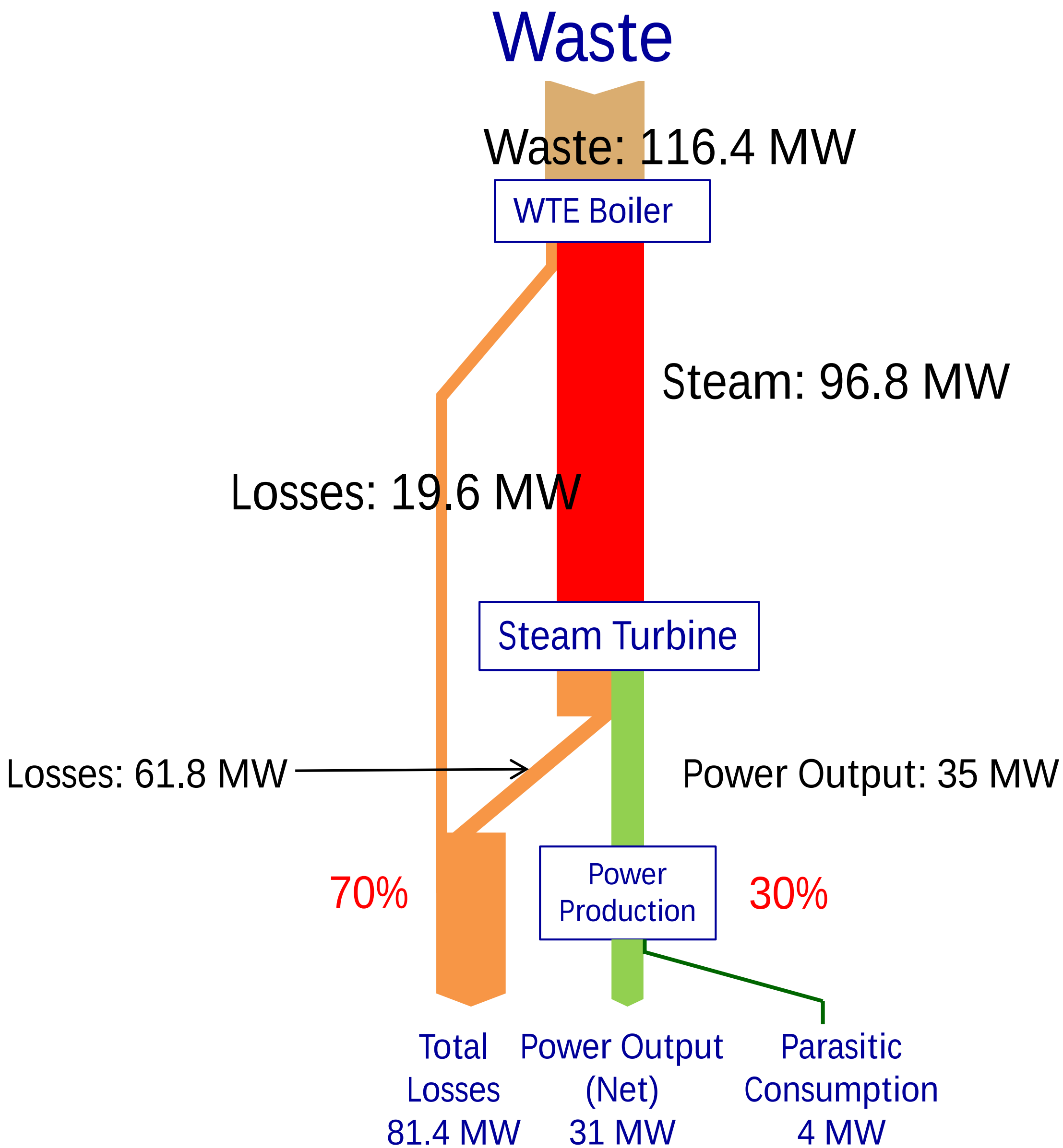
WTE Benefits Include Waste Sterilization, along with 90% Volume and 75% Weight Reduction

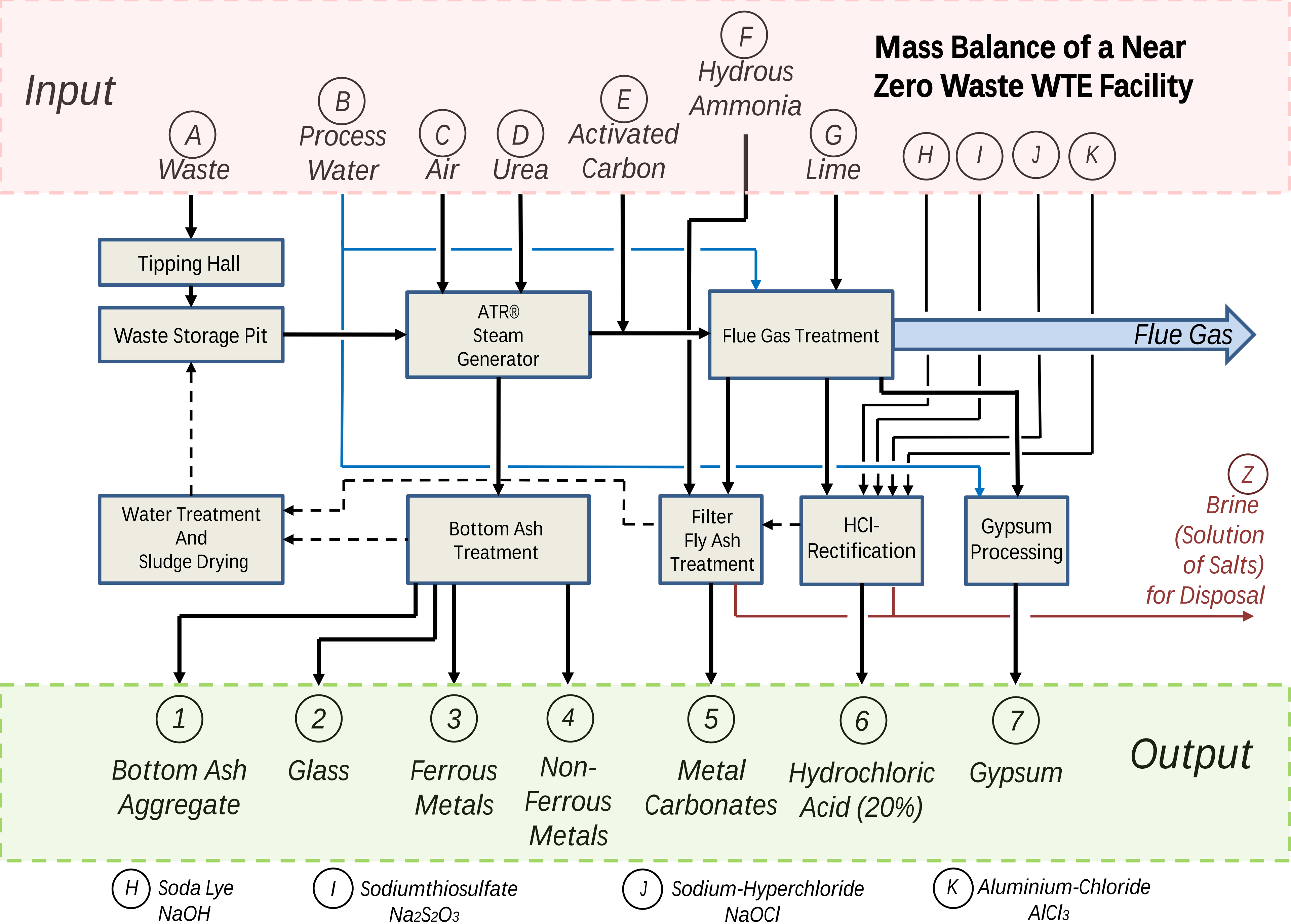
Input

Output

Waste in, stabilized and inert ash out!

Energy Balance: Traditional Waste To Energy Process





Mass Balance of a Near Zero Waste WTE Facility
Input
A Waste
B Process Water
C Air
D Urea
E Activated Carbon
F Hydrous Ammonia
G Lime
H
I
J
K
Tipping Hall
Waste Storage Pit
ATR® Steam Generator
Flue Gas Treatment
Flue Gas
Water Treatment And Sludge Drying
Bottom Ash Treatment
Filter Fly Ash Treatment
HCl-Rectification
Gypsum Processing
Z Brine (Solution of Salts) for Disposal
Output
1 Bottom Ash Aggregate
2 Glass
3 Ferrous Metals
4 Non-Ferrous Metals
5 Metal Carbonates
6 Hydrochloric Acid (20%)
7 Gypsum
H Soda Lye NaOH
I Sodiumthiosulfate Na2S2O3
J Sodium-Hyperchloride NaOCl
K Aluminium-Chloride AlCl3

Two Approaches Considered for Size of WTE
Option 1A – Maximize Use of WTE Capacity

- Maximize capacity of WTE at start of commercial operation
- Advantages include:
  - Allows unit to be operated optimally at its design condition
  - Smaller WTE facility results in lower capital cost
  - Provides incentive for future recycling programs to accommodate growth in waste generation
- Disadvantages include:
  - Excess bypass waste requiring alternate disposal grows annually
  - Eliminates opportunity for regional project
  - Eliminates opportunity for marketing of special waste program

Sizing of WTE Facility
Option 1B –Eliminate Bypass Waste

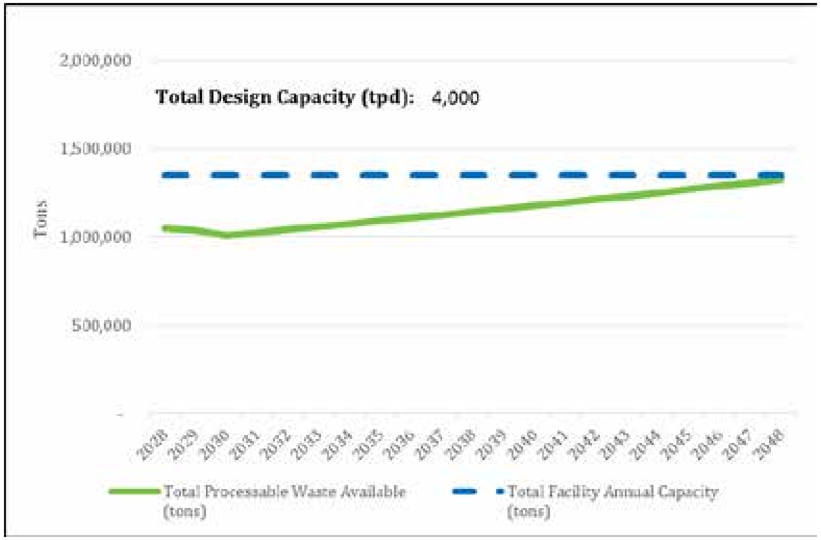
- Eliminate bypass waste throughout the duration of commercial operation period
- Advantages include:
    - Reduces reliance, cost and environmental impacts associated with alternate disposal method
    - Provides capacity to accommodate future growth
    - Excess capacity may be marketed to neighboring communities

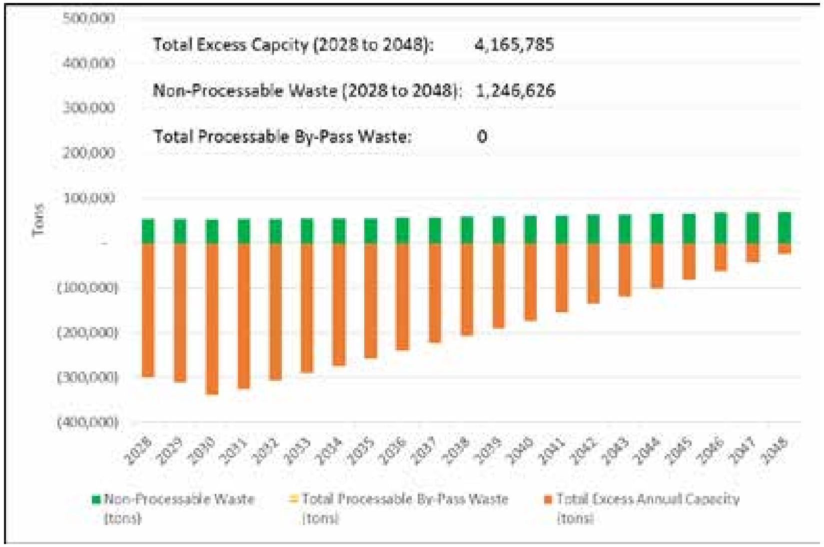
- Disadvantages include:
    - Unused capacity in early years of operation may prevent units from being operated optimally at its design condition
    - One or more combustion unit may need to operated at reduced load, or shutdown for a day on weekends
    - Larger WTE facility results in higher capital cost than Option 1A
    - Reduces incentives for future recycling programs

Scenario 1B - 20 Year Planning Horizon (No Bypass Waste/29% Excess Capacity Year 1)

Facility in Year 2028: 4 Units; Size: 1,000 tpd

Total Capacity: 4,000 tpd

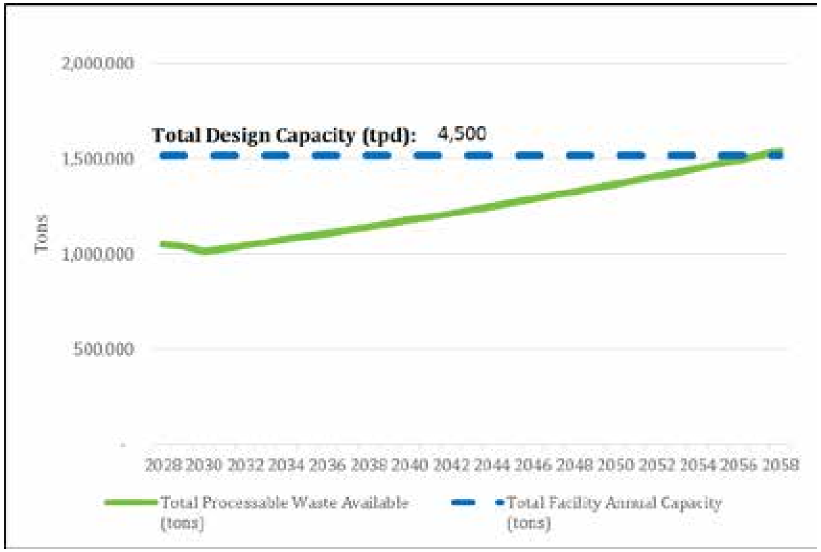


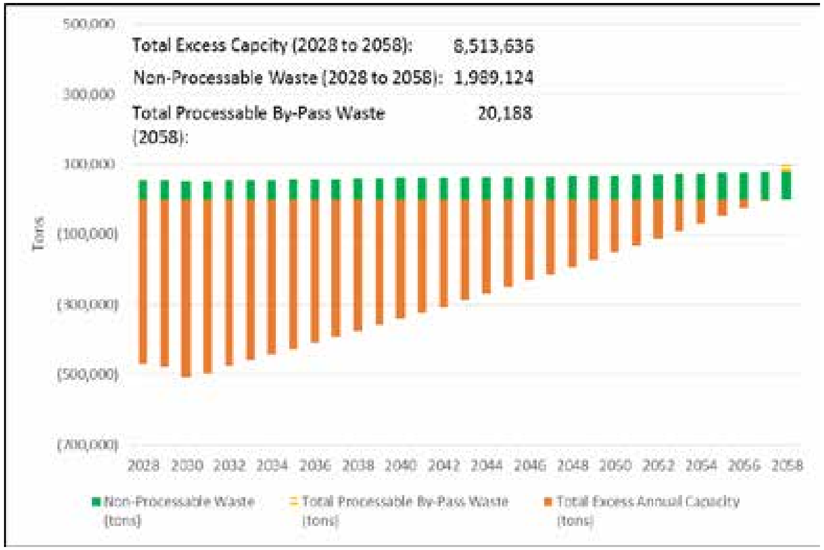


Scenario 2B - 30 Year Planning Horizon (No Bypass Waste/45% Excess Capacity Year 1)

Facility in Year 2028: 4 Units; Size: 1,125 tpd

Total Capacity: 4,500 tpd



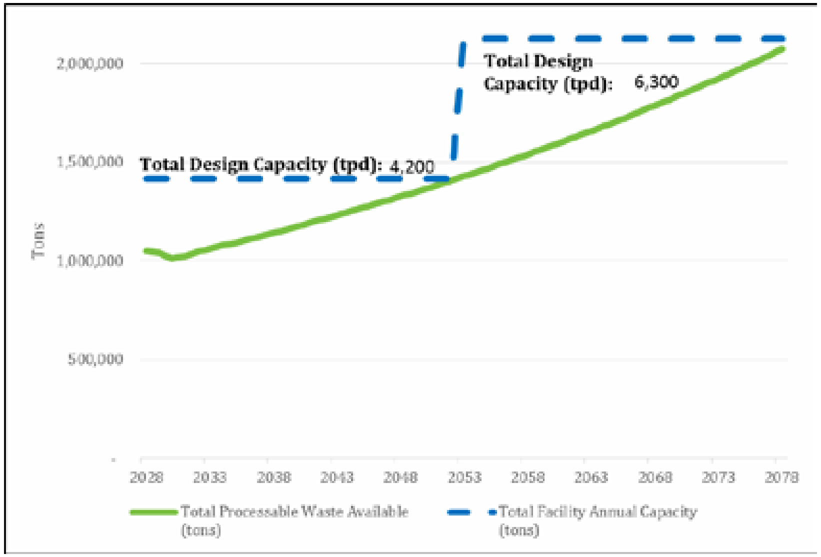


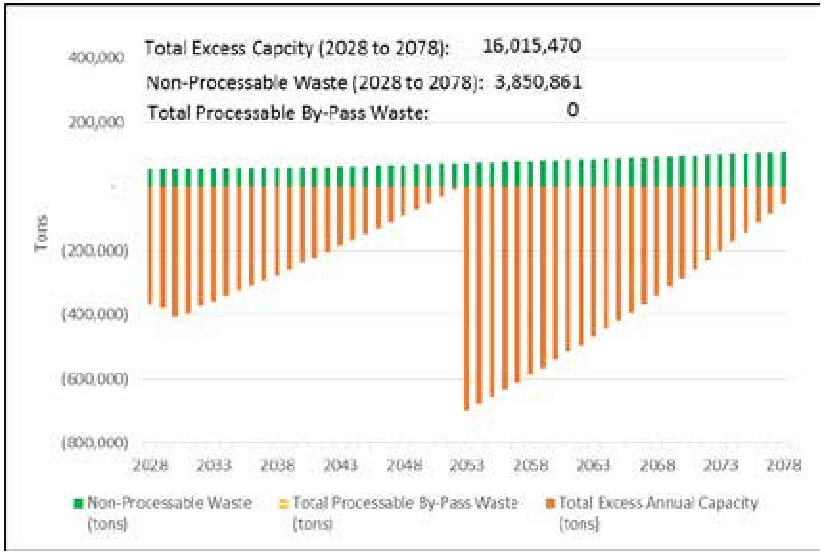
Scenario 3B - 50 Year Planning Horizon (No Bypass Waste / 28% Excess Capacity Year 1 34% Excess Capacity Year 26)

Facility in Year 2028: 4 Units; Size: 1,050 tpd

Facility Expansion in Year 2053: 2 Units; Size: 1,050 tpd

Total Capacity: 6,300 tpd





Reference WTE Facilities (large capacity)

- Shenzhen, China (5,612 tpd total capacity)
  - 6 B&W Volund Massburn units @ 920 tpd under construction
- Palm Beach County, Florida (3,000 tpd total capacity)
  - 3 B&W Volund Massburn units @1,000 tpd in operation since 2015
- Honolulu, Hawaii (900 tpd total capacity for expansion unit)
  - 1 Martin Massburn unit @ 900 tpd in operation since 2012
- Pinellas County Florida (3,150 tpd overall capacity)
  - 3 Martin GmbH Massburn units @ 1,050 tpd in operation since 1985
- Delaware Valley, Pennsylvania (3,510 tpd overall capacity)
  - 6 O'Connor Rotary Combustors @ 585 tpd in operation since 1992

NOTE: the last two WTE projects in the U.S. (Palm Beach County and Honolulu) were implemented by communities with existing RDF WTE facilities, and they chose massburn technology for expansion

Additional Benefits of WTE Implemented by WTE Owners in N.A.

- Combined heat and power (CHP) applications
  - Hennepin County, MN; Indianapolis, IN; Durham York, BC; Dublin, IR
- Internal use of electricity
  - Hillsborough County, FL; Lee County, FL
- Recycling of landfill leachate / stormwater in WTE process
  - Pinellas County, FL
- Co-combustion of tires (5%), used oils (5%), auto shredder residue, WWTP biosolids (10%), bulky and construction wastes
  - Honolulu, HI
- Co-combustion of construction and demolition waste
  - Lee County, FL
- Co-combustion of special wastes in need of assured destruction (USDA regulated garbage, medical waste, solid waste and liquid waste)
  - Honolulu, HI; Tulsa, OK; Huntsville, AL, numerous other facilities

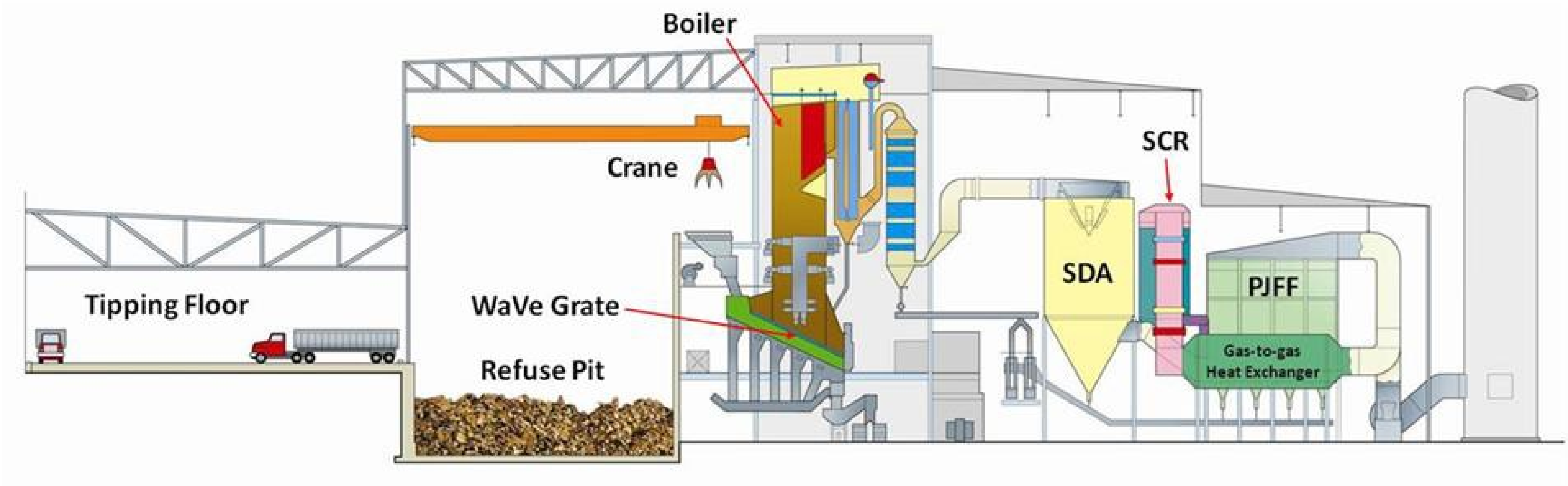
Pinellas County FL Industrial Water Treatment Plant Recycles Leachate/Stormwater for use in WTE Process

Summary of Features for Best Fit WTE Option

(refer to Final Report Table)

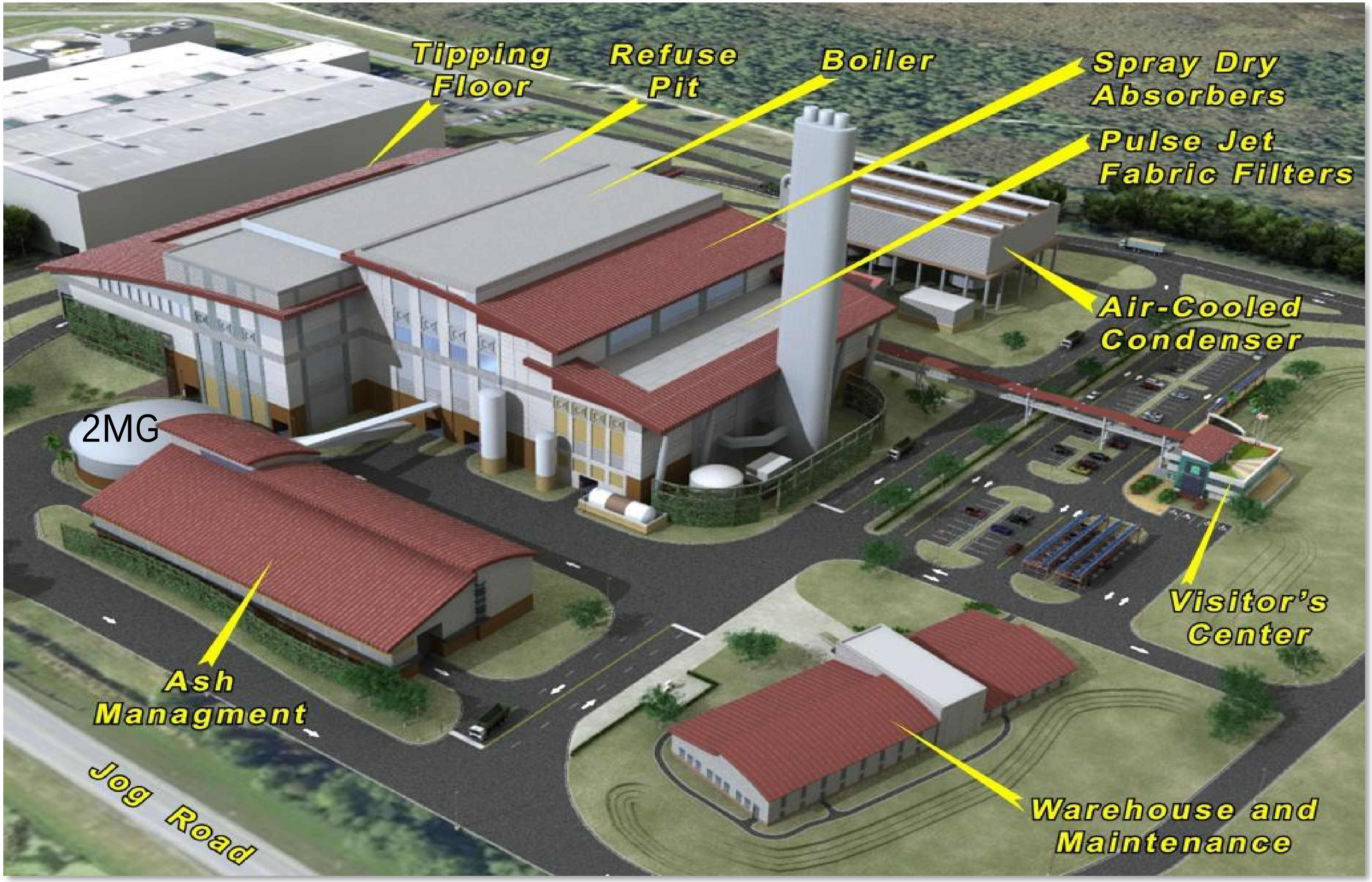
- Advanced combustion on movable grate with waterwall boiler
  - Expert combustion control system
  - Medium steam pressure, net generation of 609 kWh/ton
- Advanced air pollution control system
  - Spray Dryer Absorber (SDA), Fabric Filter (FF) with catalytic filters
  - Injection of urea/ammonia for NOx control
  - Injection of powered activated carbon for mercury / dioxin control
  - Injection of pebble lime slurry for acid gas control
- Advanced metal recovery system
  - Optimized recovery of ferrous and non-ferrous metals
  - Recovery of minerals and glass for local recycling opportunities
- Rainwater harvesting, air cooled condenser and zero liquid discharge to minimize demand on local water supplies
- Fully enclosed, architecturally pleasing buildings and landscaping

Typical Combustion WTE Facility Cross-Section



Based upon B&W Volund technology employed at Palm Beach County Florida

Reference Facility – Palm Beach County FL (enhanced aesthetics and sustainability features)



Palm Beach County FL WTE Facility
3,000 TPD – 75 MW Net Electrical Output

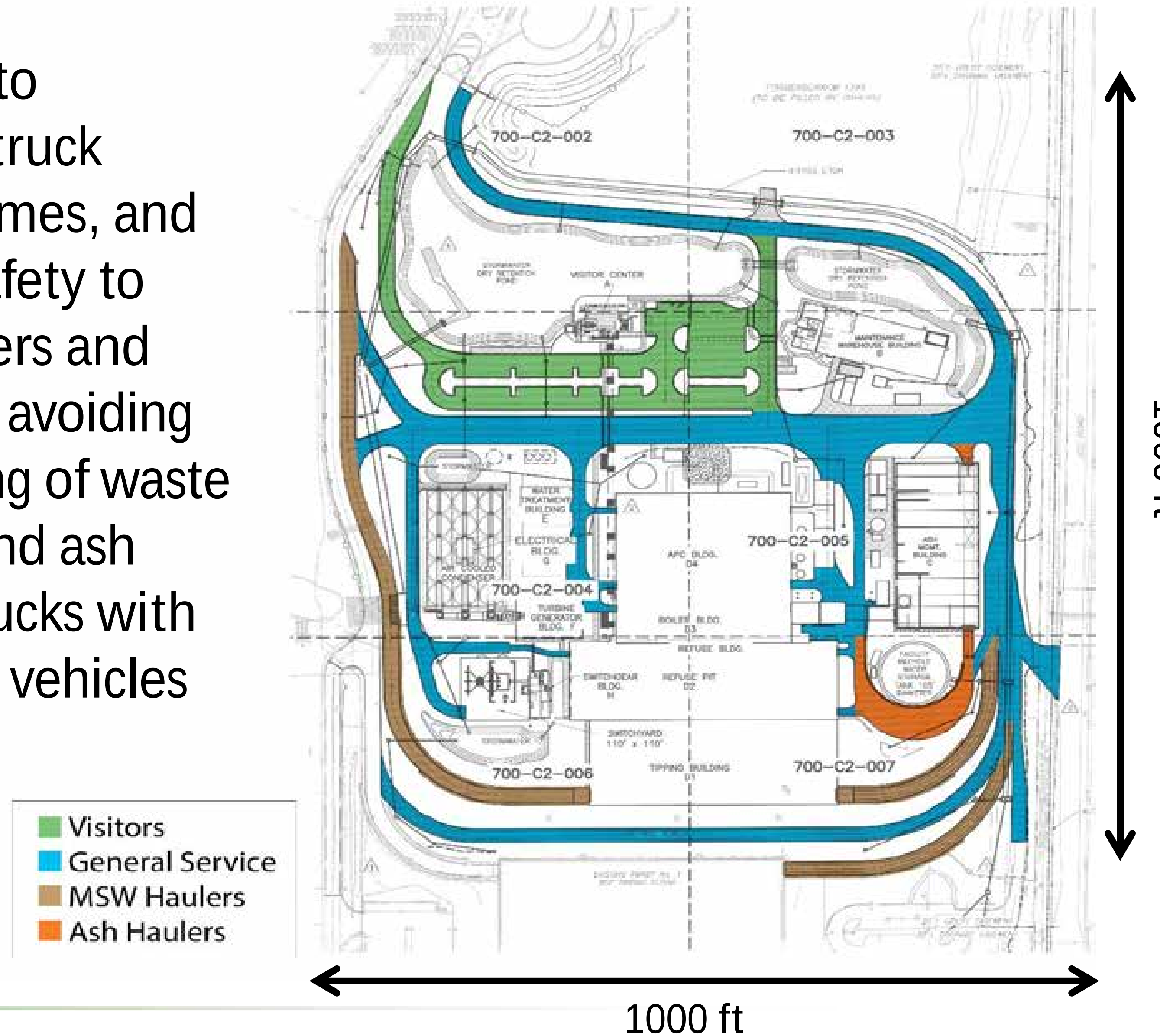
New 3,000 tpd WTE Facility Located Adjacent to Existing 2,000 tpd RDF WTE Facility

LEED Platinum Education Center

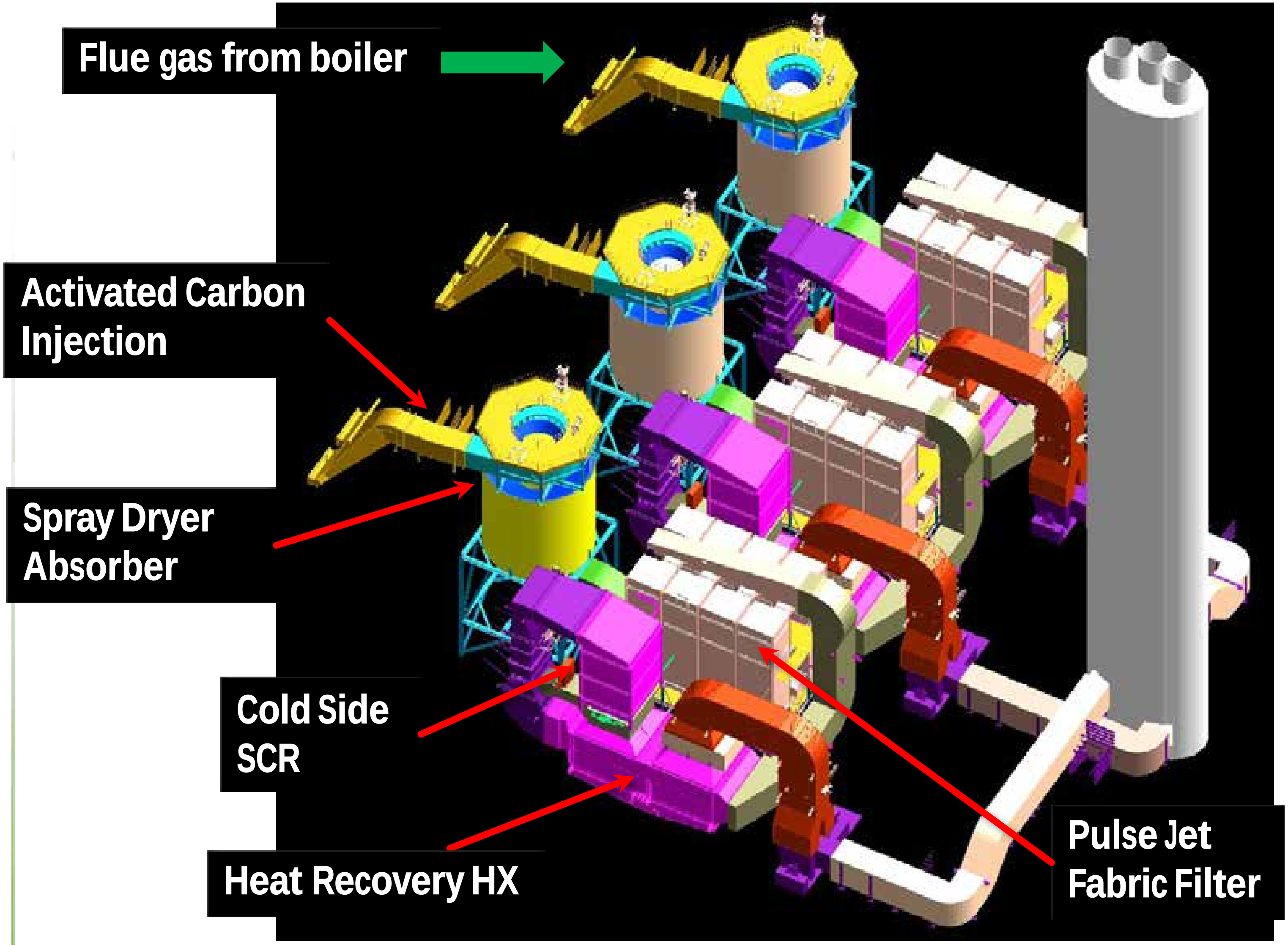
Fully Enclosed
Waste Receiving Building with 24 Truck Bays

Efficient and Safe Network of Roads and Driveways

- Designed to minimize truck delivery times, and provide safety to system users and visitors by avoiding co-mingling of waste delivery and ash hauling trucks with passenger vehicles



Palm Beach County WTE Facility Emission Control Technology



Credit: Babcock and Wilcox

Palm Beach County Florida Emission Profile

PROVEN RESULTS

Pollutant	Maximum Permit Concentration	Test Results*	Control Technology
NO_x	50 ppm	30 – 31 ppm	SCR
SO_2	24 ppm	11 – 21 ppm	SDA
CO	100 ppm	16 – 24 ppm	Optimized combustion design
Opacity	10%	0.4 – 2.4%	Fabric filter
VOCs	7 ppm	0.2 – 2.7 ppm	Optimized combustion design
Particulate Matter (PM)	12 mg/dscm	0.6 – 2.5 mg/dscm	Fabric filter
Pb	125 µg/dscm	0.5 – 8.1 µg/dscm	Fabric filter
H_2SO_4	5 ppm	Non-detectable < 0.01 ppm	SDA
HCl	20 ppm	1.5 – 2.1 ppm	SDA
HF	N/A	Non-detectable < 0.1 ppm	SDA
Dioxins/Furans	10 ng/dscm	0.2 – 0.4 ng/dscm	PAC, SCR
Hg	25 µg/dscm	0.6 µg/dscm	PAC
Cd	10 µg/dscm	0.3 – 2.5 µg/dscm	Fabric filter
NH_3 slip	10 ppm	2.2 – 5.5 ppm	Optimized SCR design

**Corrected to 7% O_2 dry basis*

PAC = Powdered activated carbon
SCR = Selective catalytic reduction
SDA = Spray dryer absorber

Credit: Babcock and Wilcox

Global WTE Overview

- More than 2,000 WTE facilities in operation 2017
- China is building on average 50 WTE facilities per year (already more than 450)
- Europe has more than 600
- US has 77 facilities

WTE EU – MVR, Hamburg, Germany


- One of the most advanced Thermal Treatment Facilities to date – Combined Heat and Power
- 1,000 tons per day
- State of the Art Fluegas Treatment
- 18 Year proven track record
- City/State of Hamburg & surrounding area = zero waste to landfill area with start up of operations in 1999
- Advanced bottom ash processing

WTE EU – Rothensee, Germany

- First facility was so successful that a second identical one was build right next to it
- Total capacity 2,000 tons per day
- Combined Heat and Power

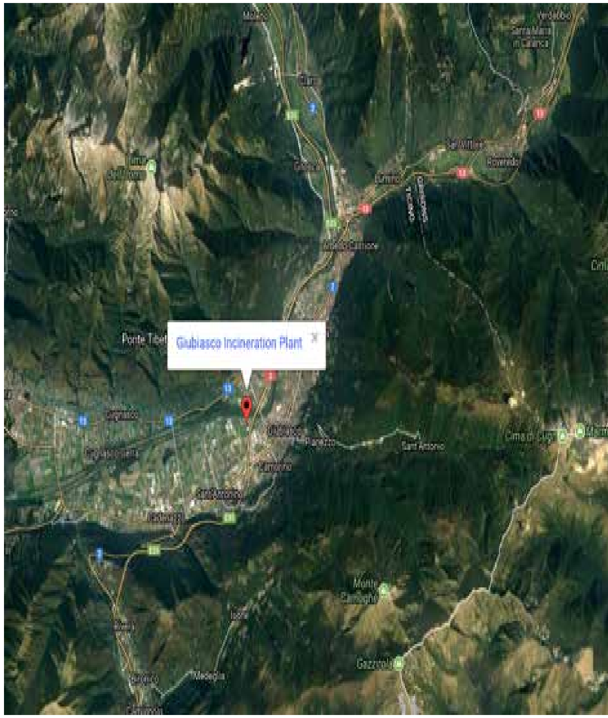
WTE EU – Copenhagen ‘Copenhill’, Denmark

- One of the newest facilities
- 1,850 tons per day
- 28% Electrical Efficiency
- Bottom Ash processing
- Combined Heat and Power
- Ski slope, Hiking and Climbing
- Integral part of the goal to make Copenhagen the first zero-carbon City by 2025

WTE EU – Brescia, Italy


- Largest combustion line for biomass worldwide
- Avoids 760 kg of CO_2 per ton of waste over state of the art landfill
- Energy Efficiency (Electric) > 27%
- Combined heat and power
- Tipping Fee $65/ton
- 1,600 tons per day

WTE EU – Giubiasco, Switzerland



- Start of operations 2009
- Recipient of Architectural Awards
- Surrounded by Vineyards and Farmland – within 500 feet of residential area
- In valley surrounded by mountains
- Treats solid waste and waste water (sewage)

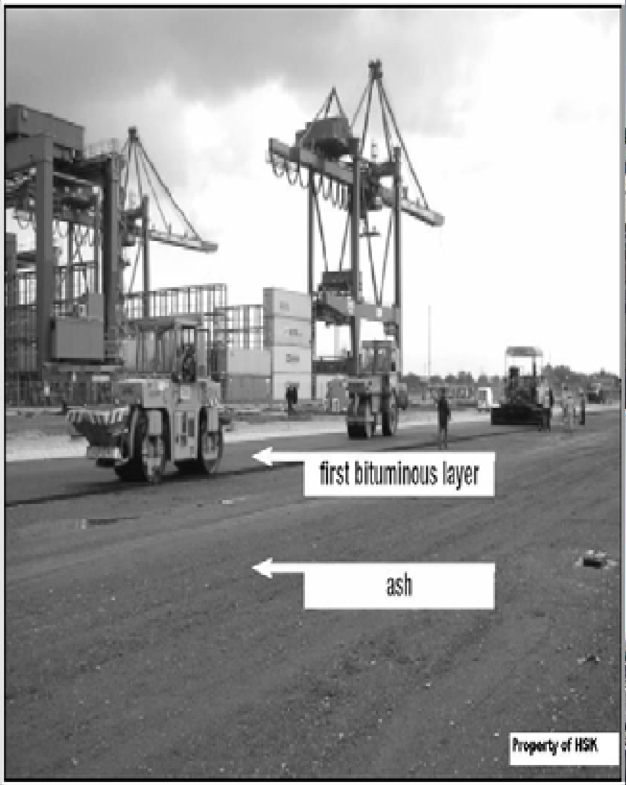
WTE EU – Amsterdam, The Netherlands

- 4,200 tons per day (largest European WTE facility) from Amsterdam and 27 neighboring municipalities
- Highest energy recovery at over 30% electric
- Bottom Ash Utilization
- Metal Recovery
- Combined Heat and Power
- Part of an integrated waste management system that has over 60% recycling
- Can supply power for 320,000 households

WTE EU - Oslo, Norway 2017

- Pilot test completed in 2016
- Plant to proceed to full scale production

500,000 tons of Bottom Ash used as carrying layer for most advanced container terminal in the world in Hamburg Germany:

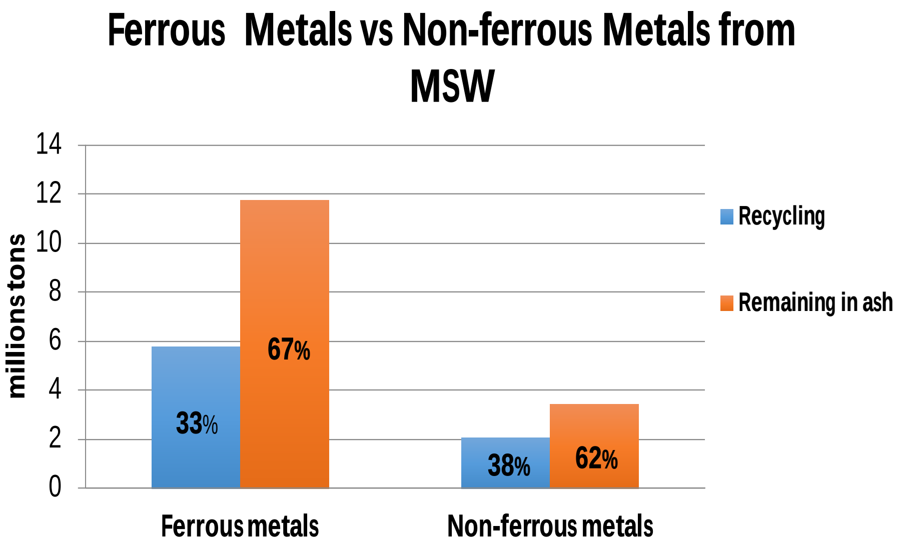


neoMER
Innovations in Sustainable Business Development

Cruse Terminal Hamburg – Built on Bottom Ash

Recovery of Metals from WTE Bottom Ash can Play a Significant Role in Community's Recycling Program

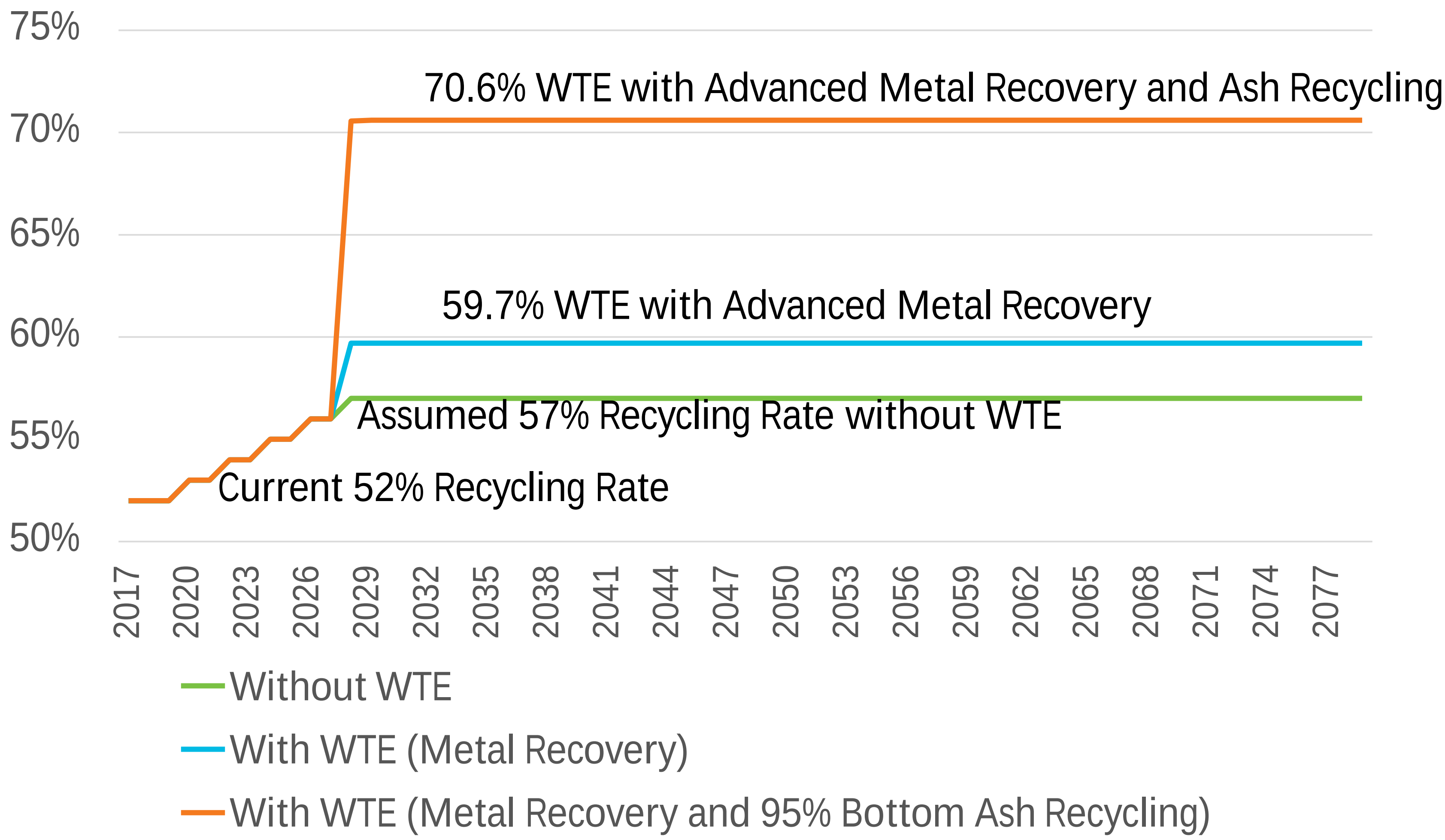
Two thirds of metals generated by residential households end up in the mixed waste mainly because they are not targeted for recycling in source-separation recycling programs



- Conventional WTE ash processing systems typically target the recovery of native metals greater than 12 millimeters (0.47 inches) in size.
- Advanced metal recovery systems utilizing recently developed new technologies improve the metal recovery rates by targeting metals less than 12 millimeters (0.47 inches) in size.

Credit: SWANA Advanced Research Foundation

Impact of Metal Recovery and 95% Bottom Ash Recycling on Overall King County Recycling Rate



Metals “Liberated” by Combustion and Recovered by Stronger Magnets and ECS – 2nd Generation

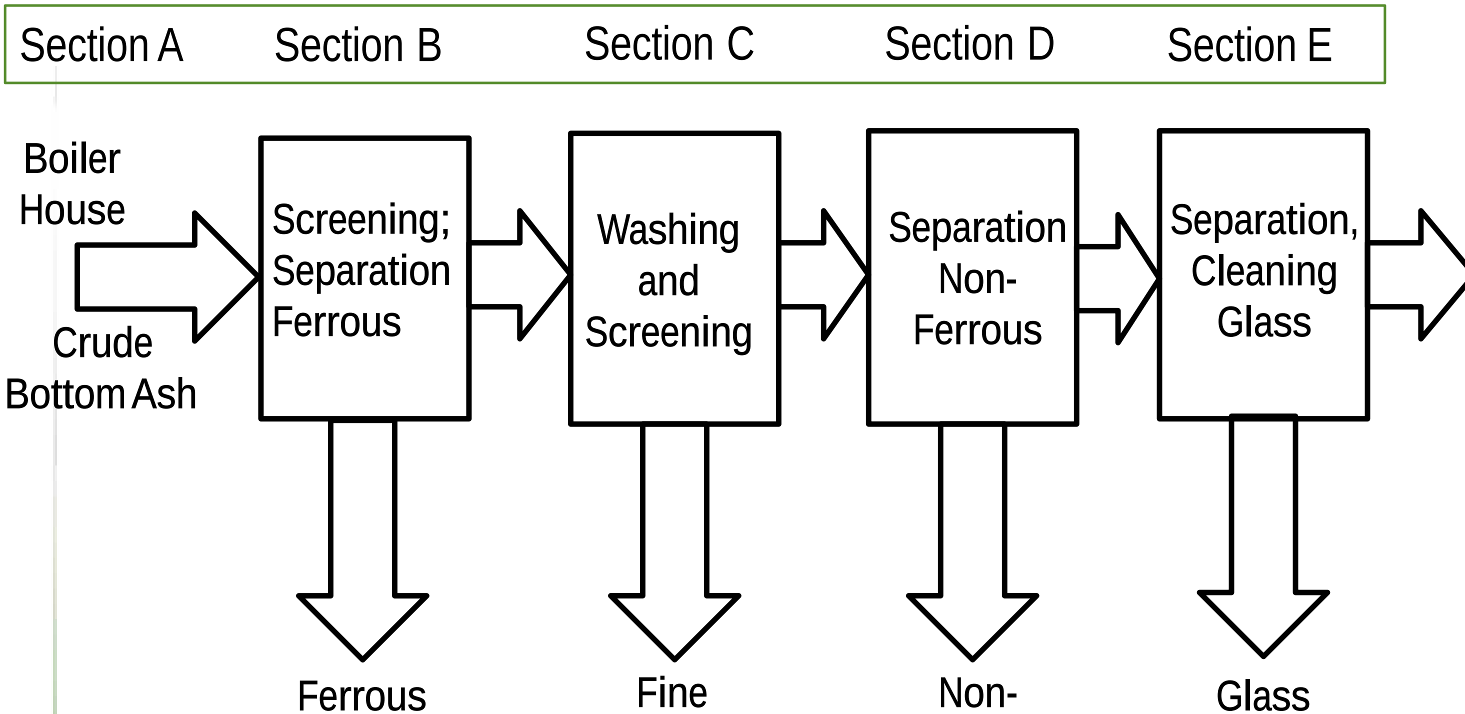
Plus 6” Ferrous Metals

Minus 6” Ferrous Metals

+3/8” Non-ferrous Metals

Close-up of Non-ferrous Metals

European Advanced Bottom Ash Treatment
Main Process-Steps



Bottom Ash Aggregate

3rd Generation WTE (Advanced Resource Recovery) Samples of “Fine” Minerals and Metals from Ash

Fine minerals
(< 0.07 inch)

Mineral aggregates
(> 0.07 inch)

Non-ferrous concentrate

Ferrous concentrate

Credit: InAshCo

Percent of Estimated Value of Non-Ferrous Metals in Ash

Aluminum 34%

Gold 28%

Copper 23%

Iron 10%

Silver 3%

Zinc 2%

Lead 1%

Recovered Aluminum Products
Light Non-ferrous Metals from WTE Bottom Ash

Aluminium scrap product (fine)
- 0.04 – 0.14 inch
- 70 - 75% pure metal scrap

Aluminium scrap product (middle)
- 0.14 – 0.4 inch
- 75 - 80 % pure metal scrap

Aluminium scrap product (coarse)
- 0.4 – 0.75 inch
- 85 - 90 % pure metal scrap

Credit: InAshCo

Heavy Non-ferrous Metals from WTE Bottom Ash

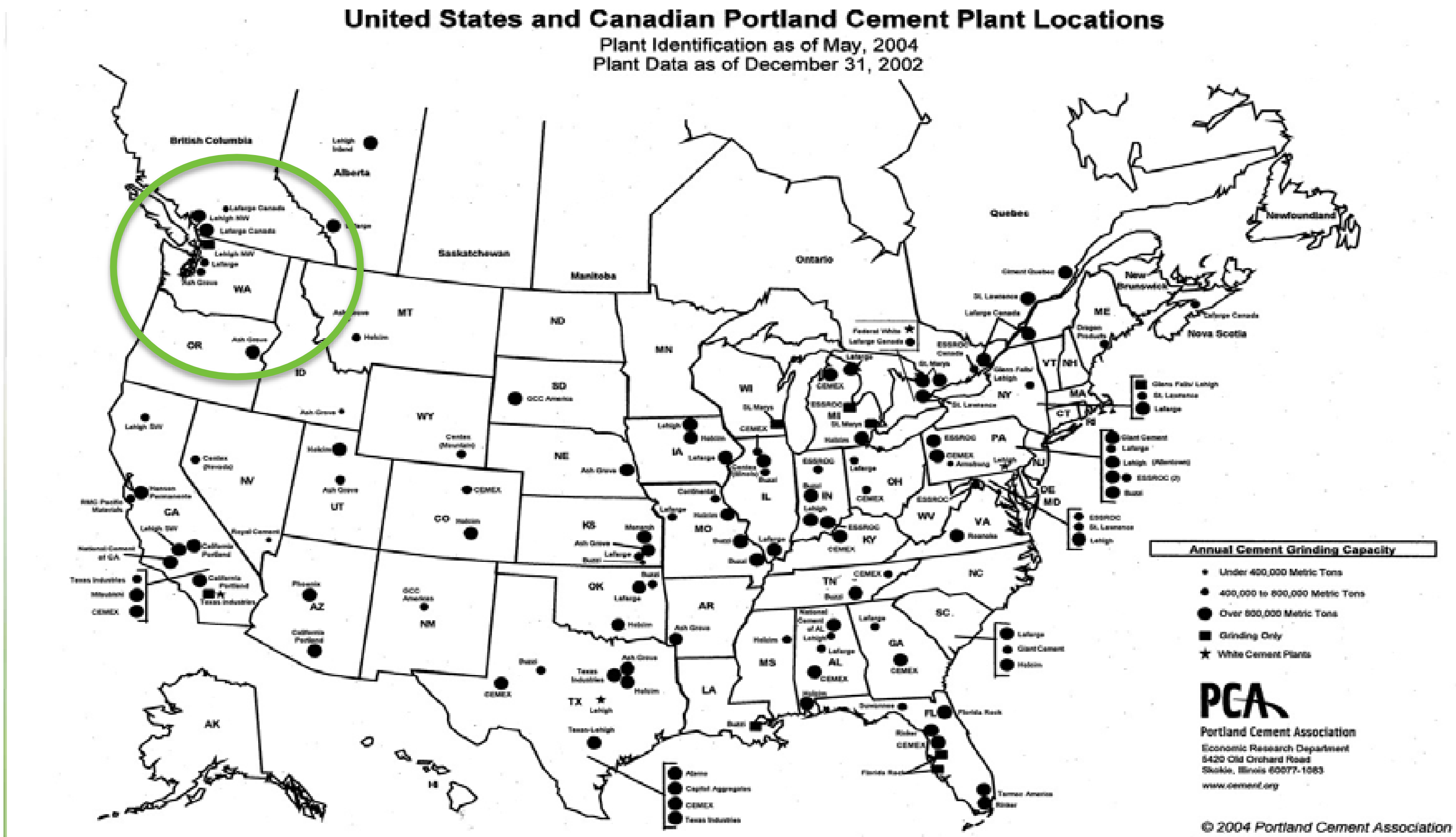
Primarily brass and copper

Credit: InAshCo

Enhanced Metal Recovery Improves Opportunities for Local Ash Recycling

- Beneficial use of bottom ash
  - Construction aggregate
    - Road base
    - Structural fill
    - Flowable fill
    - Asphalt and concrete pavements
  - Feedstock for manufacture of Portland cement
    - Source of alumina, ferric oxide, lime and silica (primary ingredients)
- Beneficial use of combined ash
  - Construction aggregate
    - Road base
    - Structural fill
    - Flowable fill

Explore Opportunities for Recycling Bottom Ash at Local Cement Kilns

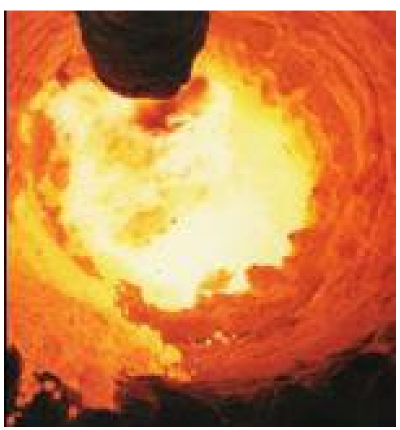


Residue Utilization: Pasco County Florida Bottom Ash Test Road Project - May 2014

- Three test sections were constructed
- FDEP approved beneficial reuse in December 2014 for three applications
  1. Bottom ash as road base
  2. Bottom ash as aggregate in asphalt
  3. Bottom ash as aggregate in concrete

WTE Bottom Ash Recycling Opportunity
Raw Material for Production of Portland Cement

Component	Portland Cement	Clinker	Typical WTE Ash
Silica (SiO_2)	18-24	22-24	24
Aluminia (Al_2O_3)	4-8	5	6
Ferric Oxide (Fe_2O_3)	2-5	0-3	3
Lime (CaO)	62-67	68-71	37



Key Parameters used for "Conservative" Financial Analysis

- Capital cost (adjusted for inflation, seismic, 8.6% sales tax, owner costs, $5M site acquisition, $15M advanced metal recovery equipment and building, $1.35M electrical interconnection, and 5% contingency)
  - Scenario 1 (4 units at 1,000 tpd) = Base cost of $237,812/tpd (2017) escalated to $341,000 /tpd (2028)
  - Scenario 2 (4 units at 1,125 tpd) = Base cost of $221,576 /tpd (2017) escalated to $318,000 /tpd (2028)
  - Scenario 3 (4 units at 1,050 tpd) = Base cost of $230,943 /tpd (2017) escalated to $332,000 /tpd (2028)
- Sales price of electricity = $0.0491 ($2028) based upon Mid-C Medium scenario of Northwest Power and Conservation Council 7th Power Plan
- Electric sales price escalated at 2% inflation (2037-2078)

Key Parameters used for “Conservative” Financial Analysis

- Net electric generation = 609 kWh/ton
- 90/10 electrical revenue sharing (owner/contractor)
- Ferrous metal recovery rate of 4.0 percent and sales price of $50/ton ($2017)
- Non-ferrous metal recovery rate of 0.8 percent and sales price of $750 ($2017)
- 50/50 metal recovery revenue sharing (owner/contractor)
- No revenues assumed from sale of RECs, VCUs or recycling of bottom ash
- Ash transportation and disposal cost of $54.44/ton
- Debt service interest rate of 5%
- Construction period of 42 months at 2% interest
- Cost to issue bonds at 1%

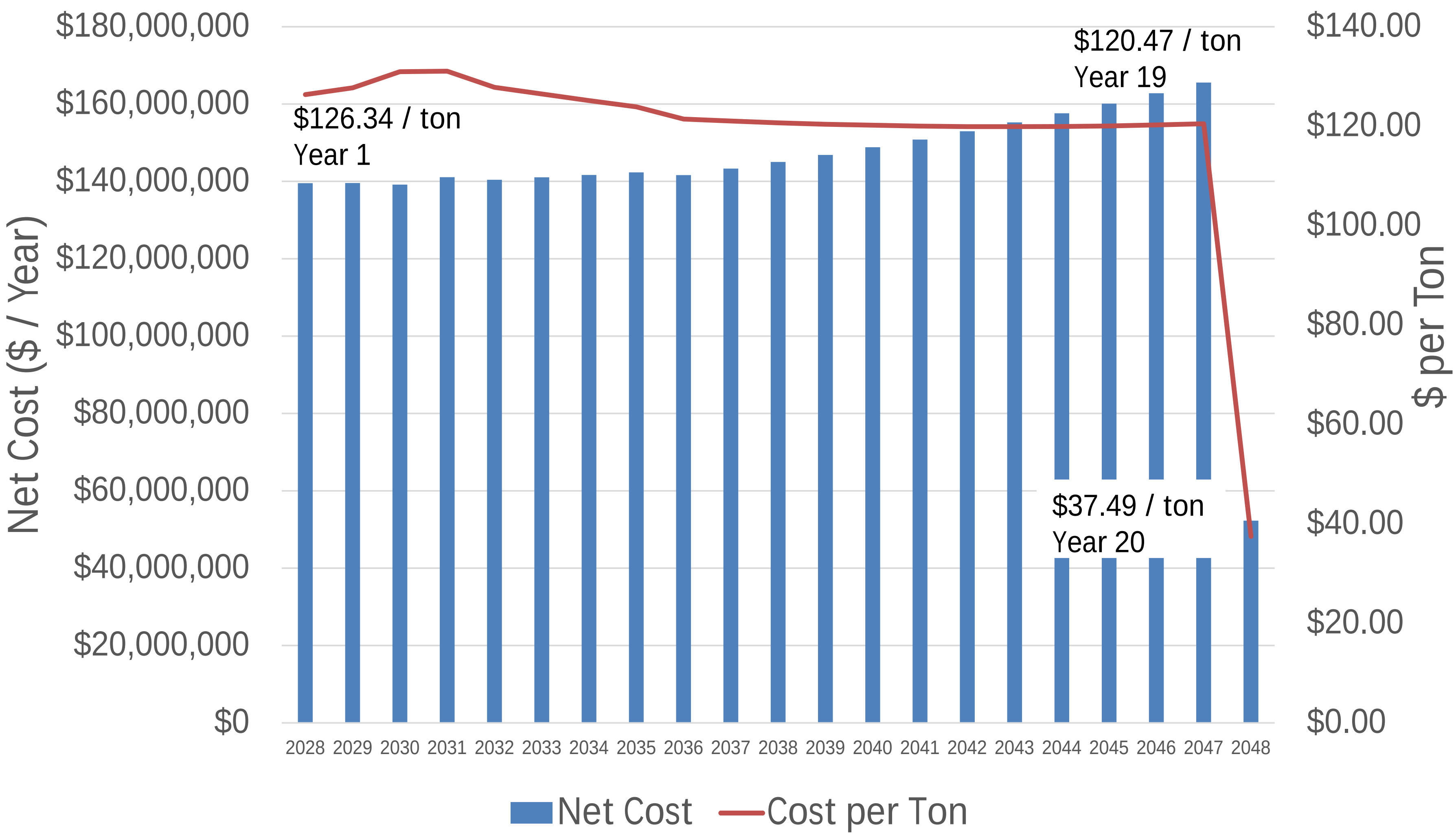
Key Parameters used for Financial Analysis

- WTE O&M service fee in year 1
  - 20-year scenario (4,000tpd) = $23.00/ton
  - 30-year scenario (4,500tpd) = $22.00/ton
  - 50-year scenario (4,200tpd) = $22.50/ton
- County annual management costs = $210,000/year
- Annual environmental consulting costs = $350,000/year

Key Escalation Factors for “Conservative“ Financial Analysis

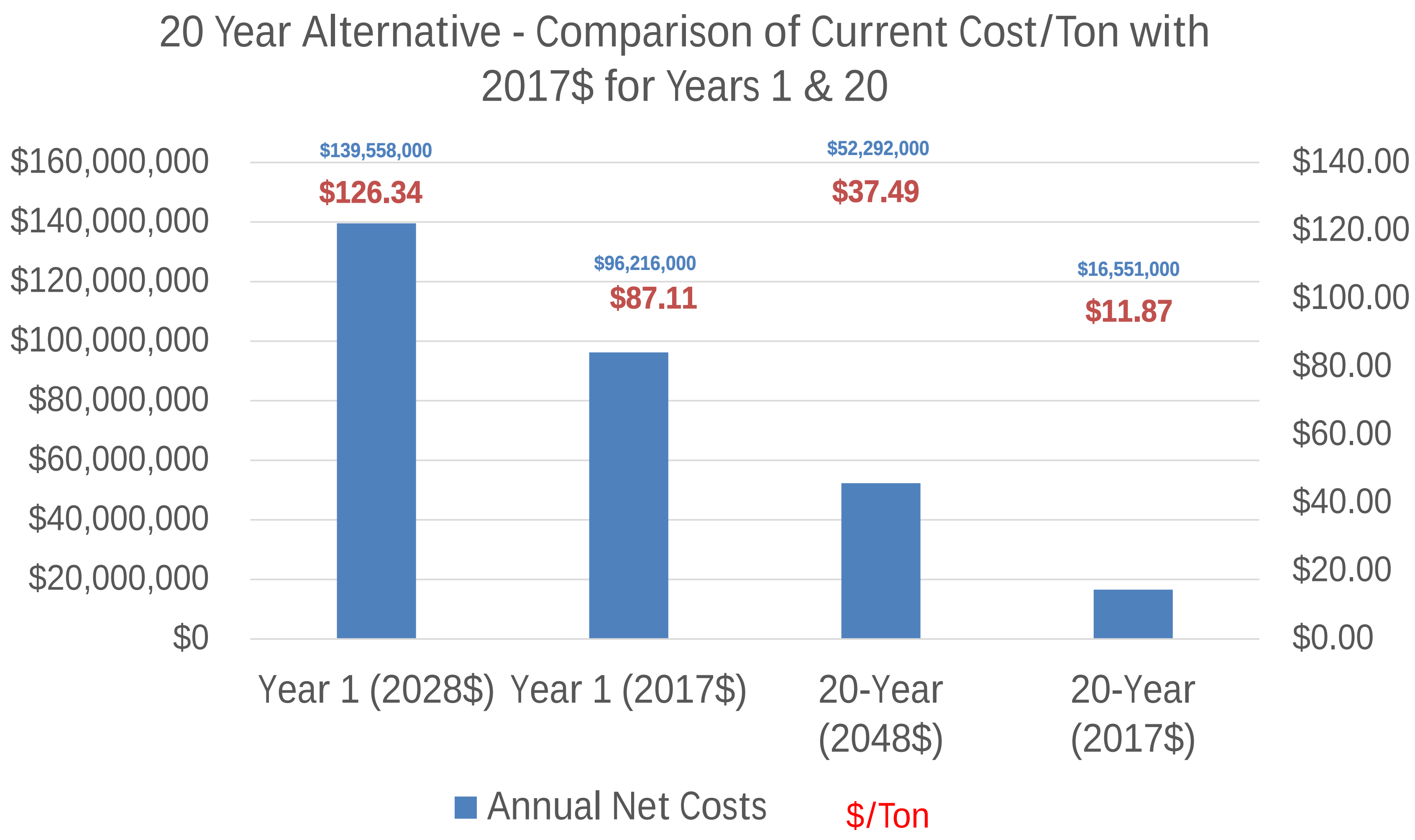
Parameter	Value	Reference
Other Revenue - Inflation	1.50%	2015 to 2017 actual increase for non-ferrous revenue - Pinellas
Electric Revenue - Inflation	2.00%	Bureau of Labor Statistics- PPI- Electric Power – average increase 2007-2017
Operating Costs - Labor Inflation	3.20%	County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, blended labor
Operating Costs - Equipment Inflation	2.80%	County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, general inflation
Operating Costs - Other Inflation	2.80%	County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, general inflation
Operating Costs - Reagent Inflation	3.00%	BLS Chemical Indexes WPU061 - Average of increase 2010-2017
Contract Operating Costs - Combined Inflation	2.90%	Equals the average of above
WTE Capital Cost - Labor Inflation	2.68%	Engineering News Record, Skilled Labor Index – average of 2012-2016
WTE Capital Cost - Equipment Inflation	1.72%	Engineering News Record, Materials Index – average of 2012-2016
WTE Capital Cost - Other Inflation	2.20%	Bureau of Labor Statistics – Machinery & Equipment (WPU114) – average increase 2010-2016

20-Year Analysis Net Cost and Cost per Ton (69% reduction upon retirement of debt)

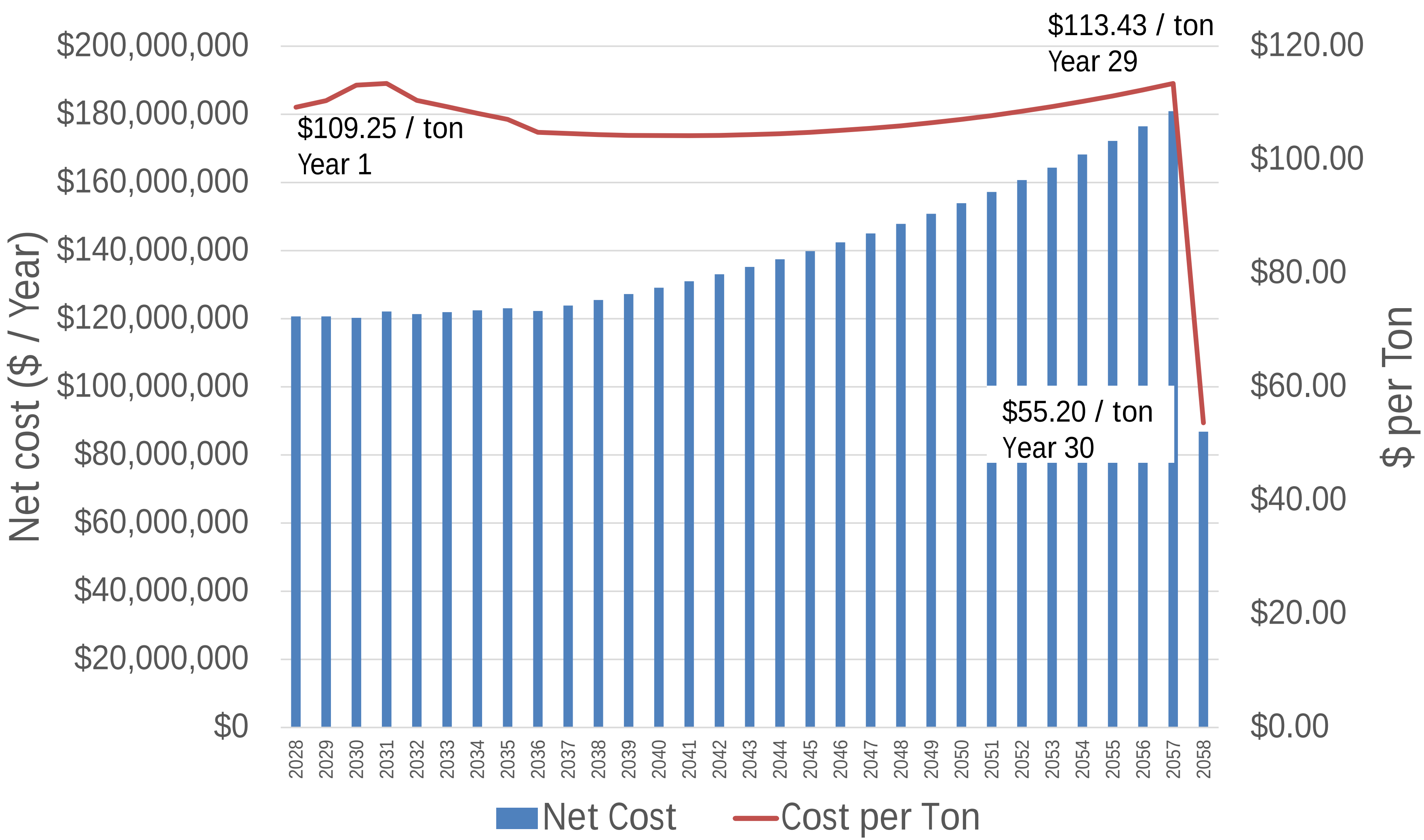


***A 20 year scenario does not consider additional investment, beyond year 20, if the County's solid waste projection continues to grow as planned**

20-Year Scenario Net Cost per Ton 2017$ for Comparison with Current Disposal Costs

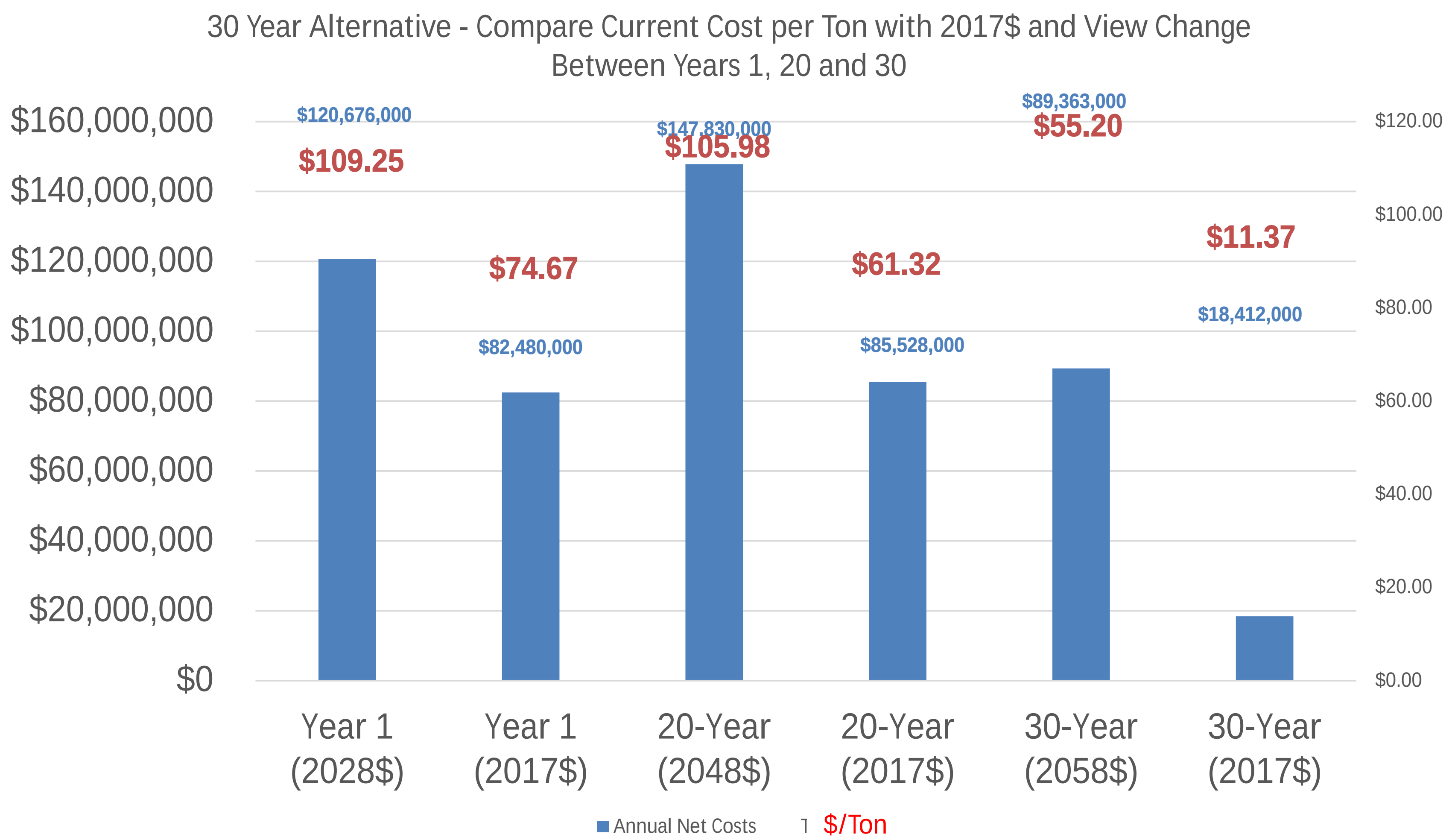


30-Year Analysis Net Cost and Cost per Ton (47% reduction upon retirement of debt)

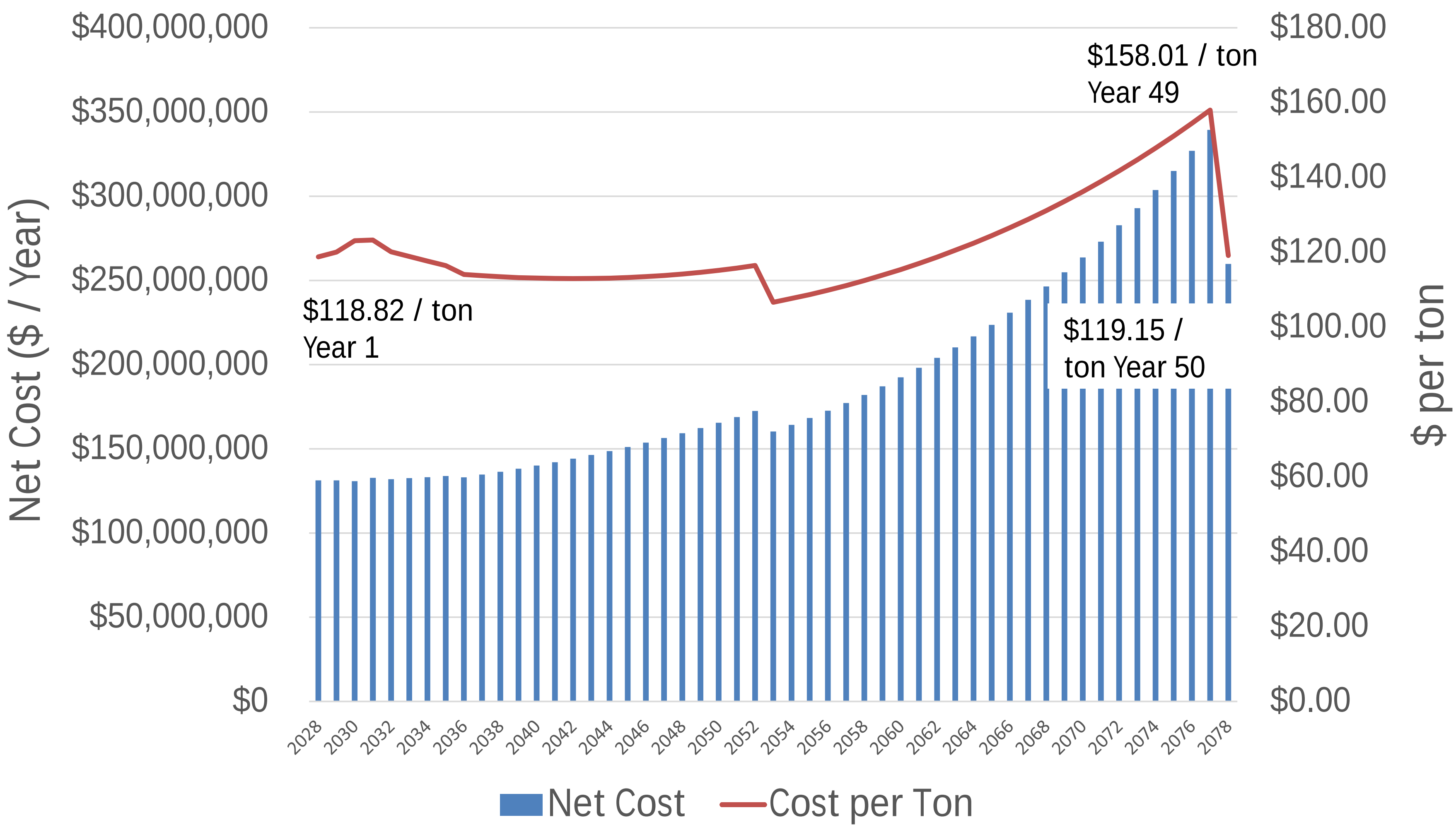


***A 30 year scenario does not consider additional investment, beyond year 30, if the County's solid waste projection continues to grow as planned**

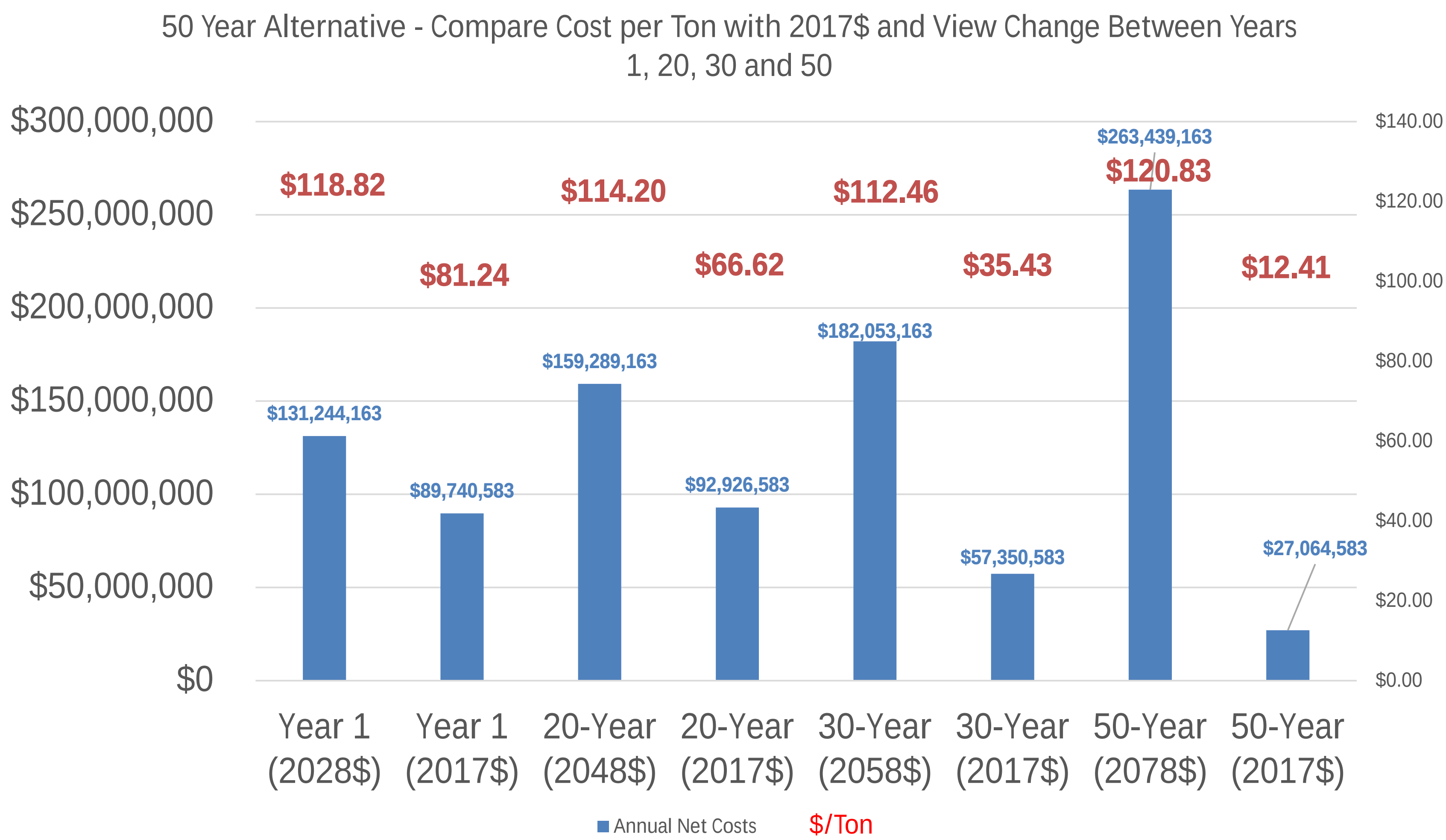
30-Year Scenario Net Cost per Ton 2017$ for Comparison with Current Disposal Costs



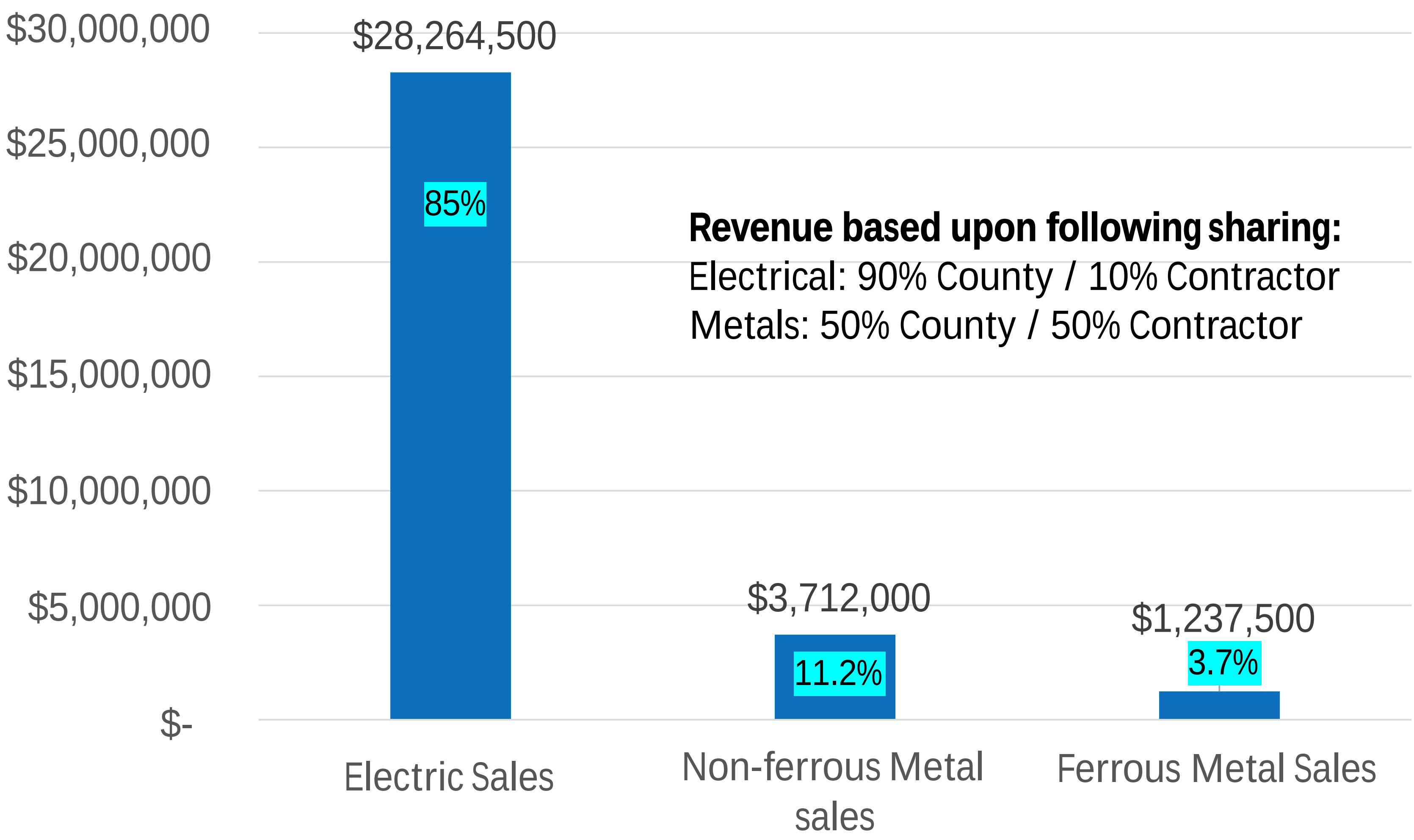
50-Year Analysis Net Cost and Cost per Ton (25% reduction upon retirement of debt)



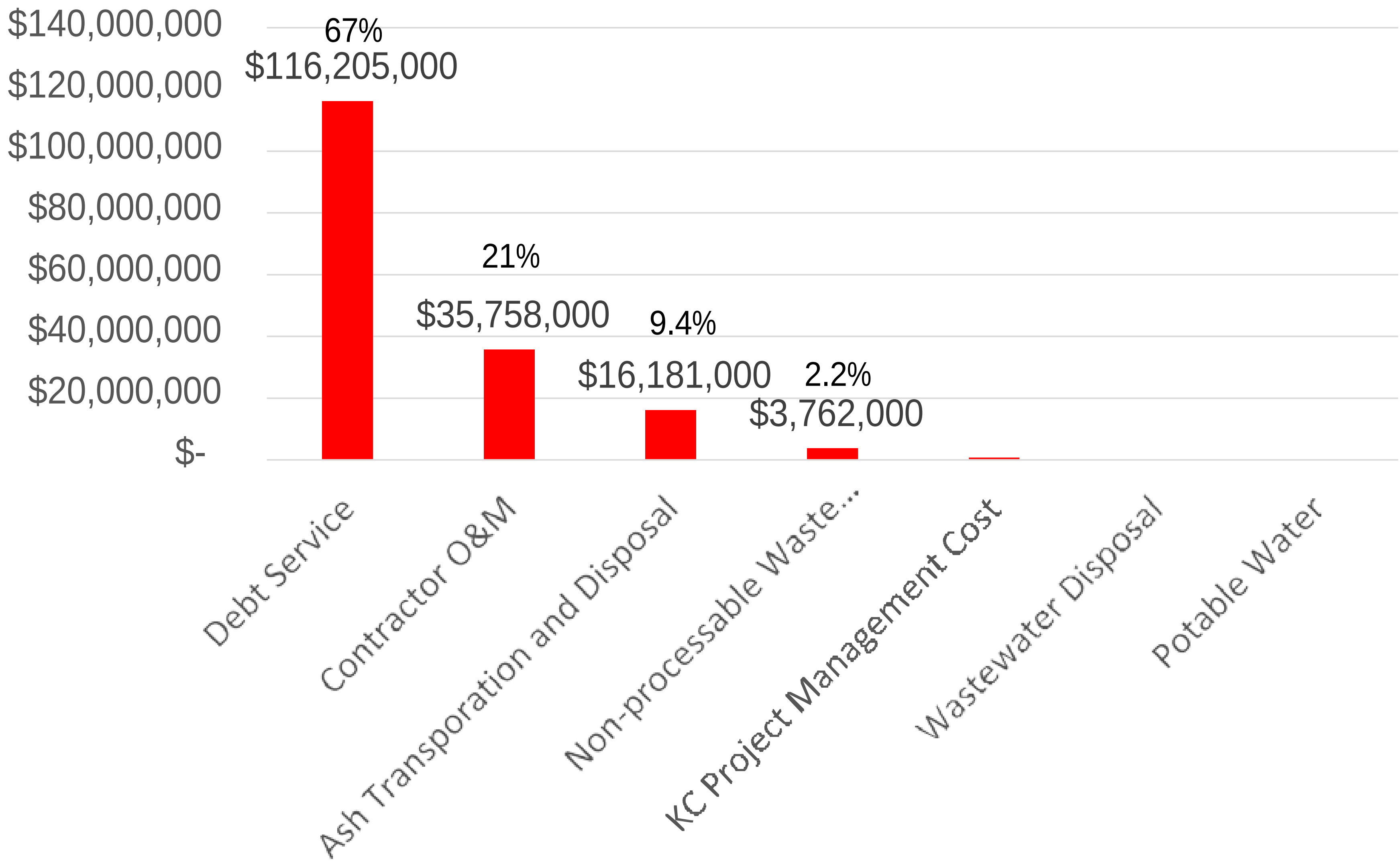
50-Year Scenario Net Cost per Ton 2017$ for Comparison with Current Disposal Costs



Summary of Year 1 Revenues - Electrical Sales are the Primary Source of Offsetting Revenues



Summary of Year 1 Costs – Capital and Debt Service is the Primary Cost Element



Sensitivity Analysis of Enhanced WTE Revenues or Reduced Costs

- Combustion of special wastes in need of assured destruction
  - Fill all of unused capacity
  - Market 10% of capacity (400 tpd)
- Internal use of all energy valued at 6 cents/kWh ($2017)*
  - Treatment of water and/or wastewater, drying and processing WWTP biosolids, other "behind the meter" uses (Public Works, recycling facilities)
- Recycle bottom ash (75% assumed)*
  - Aggregates for use in asphalt or concrete pavements / products
  - Feedstock for manufacturing of Portland cement
- Local ash disposal in lieu of remote landfill
- Additional electrical revenue (+ 1 cent / kWh)
- Sale of Renewable Energy Credits ($10/REC)
- Reduced O&M inflation rates by 0.5%
- Reduced financing interest rate by 0.5%

***Would require statutory change. The probability of this occurring is considered low without a push from the King County Council and/or State Legislature.**

Example of Successful Supplemental Waste Program in Lancaster County Pennsylvania

Special Wastes in Need of Secure Disposal can be a Significant Source of Revenues

- **Local and regional wastes in need of “secure means of disposal ”**
  - Unsalable manufactured products
  - Out-of-spec or out-of-date
  - Discarded pharmaceuticals
  - Industrial liquid and solid wastes
  - International wastes (USDA regulated garbage)
  - Auto shredder residue (ASR)
- **Wastewater treatment plant residuals and biosolids**
  - Discarded fats, oils and grease (FOG)
- **Used tires**
- **Used motr oils and lubricants**

Hillsborough County FL WTE...First to Internally Power Water Resource Facilities (no interruption during Hurricane Irma)

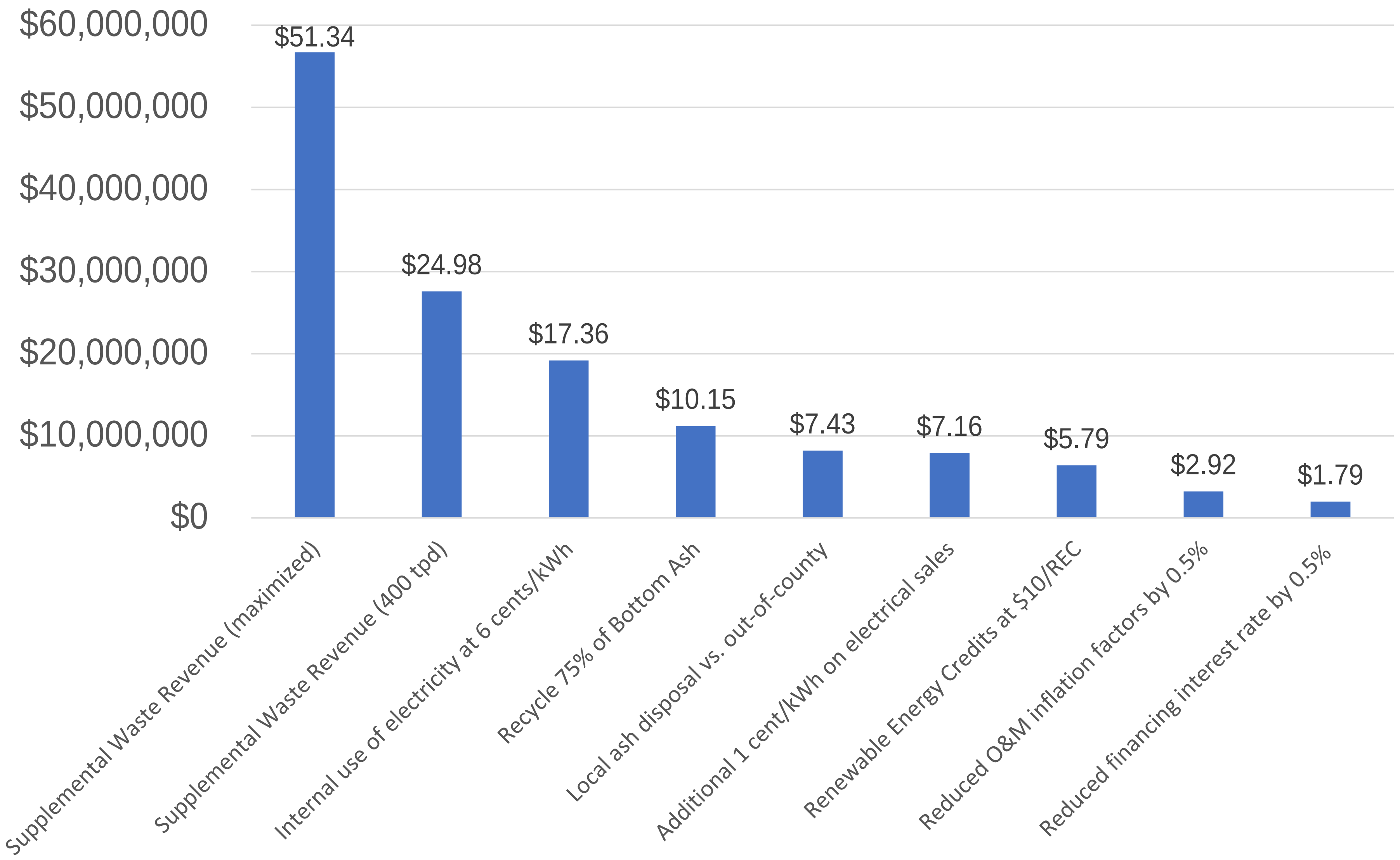
Additional Public Works Facilities may be Powered by Electricity from WTE in the Future

Similar to “microgrid” concept promoted by DOE

Summary of Sensitivity Analysis

Option	Net Gain ($)	Reduction in Base Cost (%)	Reduction in Tipping Fee ($/ton)
Supplemental Waste Revenue (maximized to fill all excess capacity)	$56,705,879	40.7%	$51.34
Supplemental Waste Revenue (400 tpd – 10% of total capacity)	$27,594,000	19.8%	$24.98
Internal use of electricity at 6 cents/kWh	$19,178,162	13.7%	$13.76
Recycle 75% of Bottom Ash	$11,211,129	8.0%	$10.15
Local ash disposal vs. out-of-county	$8,204,162	5.9%	$7.43
Additional 1 cent/kWh on electrical sales	$7,903,978	5.7%	$7.16
Renewable Energy Credits at $10/REC	$6,397,356	4.6%	$5.79
Reduced O&M inflation factors by 0.5%	$3,226,754	2.3%	$2.92
Reduced financing interest rate by 0.5%	$1,981,800	1.4%	$1.79

Summary of Sensitivity Analysis
Net Gain and Reduction in Cost/Ton



Sensitivity Analysis – Best Case (20 Year Scenario)

Options for Improved Revenues and Reduced Cost of WTE to King County Rate Payers					
			Option 1 (Best Combination)		
Option	Improved Revenues	Reduced Cost	Net Gain ($/year)	Reduction in Base Case Cost (%)	Reduction in Tipping Fee ($/ton)
Supplemental Waste Revenue (maximized to fill available capacity)	Yes		$56,705,879	40.7%	$51.34
Internal use of all electricity (valued at 6 cents/kWh in 2017$)*	yes		$19,178,162	13.7%	$17.36
Recycle 75% of bottom ash*		Yes	$11,211,129	8.0%	$10.15
Sale of RECs at $10/Rec	Yes		$6,397,356	4.6%	$5.79
Reduced O&M Inflation Factors by -0.5%		Yes	$3,226,754	2.3%	$2.92
Reduced Construction Financing Interest Rate by -0.5%		Yes	$1,981,800	1.4%	$1.79
Total Combined Benefits			**$98,701,080**	**70.8%**	**$89.37**

Possible Tipping Fee: $ 36.92

***Would require statutory change. The probability of this occurring is considered low without a push from the King County Council and/or State Legislature.**

Sensitivity Analysis – Optimistic Case (20 Year Scenario)

Options for Improved Revenues and Reduced Cost of WTE to King County Rate Payers					
			Option 2 (Optimistic Combination)		
Option	Improved Revenues	Reduced Cost	Net Gain ($/year)	Reduction in Base Case Cost (%)	Reduction in Tipping Fee ($/ton)
Supplemental Waste Revenue (400 tpd - 10% of capacity)	Yes		$27,594,000	19.8%	$24.98
Recycle 75% of bottom ash		Yes	$11,211,129	8.0%	$10.15
Additional 1 cent/kWh on electric power sales	Yes		$7,903,978	5.7%	$7.16
Sale of RECs at $10/Rec	Yes		$6,397,356	4.6%	$5.79
Reduced O&M Inflation Factors by -0.5%		Yes	$3,226,754	2.3%	$2.92
Reduced Construction Financing Interest Rate by -0.5%		Yes	$1,981,800	1.4%	$1.79
Total Combined Benefits			**$58,315,017**	**41.8%**	**$52.80**

Possible Tipping Fee: $ 73.49

Sensitivity Analysis
Options Under Control of King County
(20 Year Scenario)

Options for Improved: Revenues and Reduced Cost of WTE to King County Rate Payers					
			Option 3 (Items Controlled by KC)		
Option	Improved Revenues	Reduced Cost	Net Gain ($/year)	Reduction in Base Case Cost (%)	Reduction in Tipping Fee ($/ton)
Supplemental Waste Revenue (400 tpd - 10% of capacity)	Yes		$27,594,000	19.8%	$24.98
Disposal of all ash into local ash monofill		Yes	$8,204,162	5.9%	$7.43
Total Combined Benefits			**$35,798,162**	**25.7%**	**$32.41**

Possible Tipping Fee: $ 93.88

Conclusions from Financial Analysis

- **Conservative analysis was conducted for this project**
  - **High escalation factors may not come to fruition**
    - Variable costs doubled during first 20 years
  - **Large capacity WTE facility at year 1 (oversized by 28%-45%)**
    - WTE facility doesn't reach capacity until end of financing period
    - Excess capacity remains unused for growth in future waste generation
  - **Modest sales price of primary WTE products:**
    - Electricity sold at $49.09/MWh in 2028$, inflated by 2% per year
    - Non-ferrous metals sold at $750/ton (2017$), inflated by 1.5% per year
    - Ferrous metals sold at $50/ton (2017$), inflated by 1.5% per year
    - No revenue from sale of RECs or VCOs assumed
    - No revenue from sale of recyclable bottom ash assumed
- **Refined analysis should be conducted in future Feasibility Study**
  - **Start construction earlier**
  - **Potentially lower capital and O&M costs**
  - **Potentially higher revenues**
  - **Report all costs in 2017$**

Thank You for the Opportunity to Share! Feel Free to ask Questions

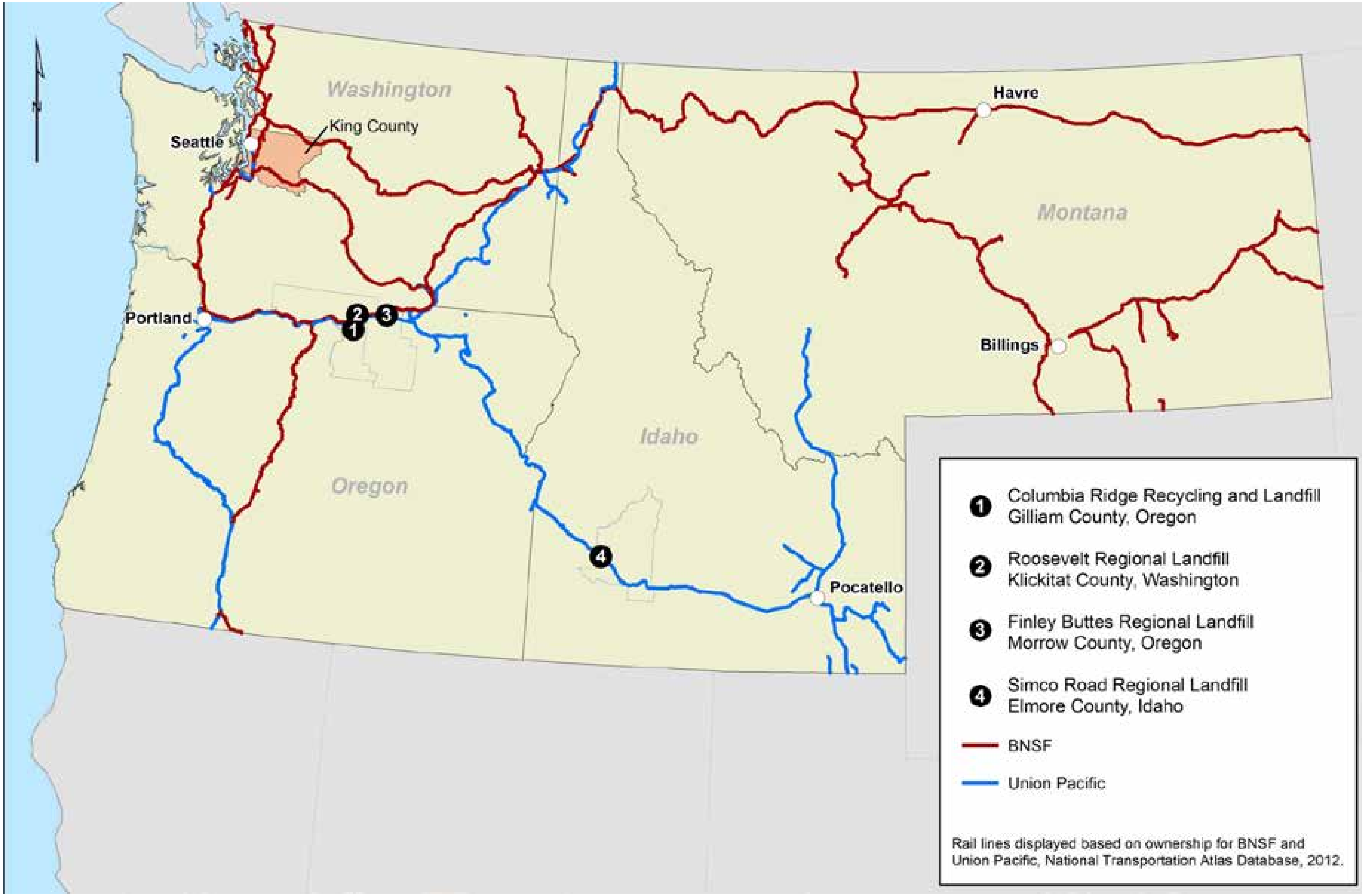
Solid Waste Export Considerations

Curt Thalken, PE

November 6, 2017

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

Regional SW Disposal Options



Remaining Permitted Capacity

Landfill	Permitted Acres[1]	Remaining Capacity (tons)[2]	Currently Receiving (tons/year)[3]	Remaining Capacity at current fill rate (years)[4]	CHRLF Tons[5]	Projected Tons/year w/CHRLF redirected (new fill rate)	Years remaining at new fill rate
Columbia Ridge	760	329,000,000	2.6 to 2.7 mill	120-140	1.1-2.2 mill	3.7-4.9 mill	67-88
Roosevelt	915	162,000,000	2.2 to 2.4 mill	70-100	1.1-2.2 mill	2.3-4.7 mill	35-70
Finley Buttes	510	131,859,000	500,000–700,000	200+	1.1-2.2 mill	1.6-2.9 mill	45-82
Simco Road	810	208,000,000	365,000 ±	150-200+	1.1-2.2 mill	1.4-2.5 mill	83-148

Sources:

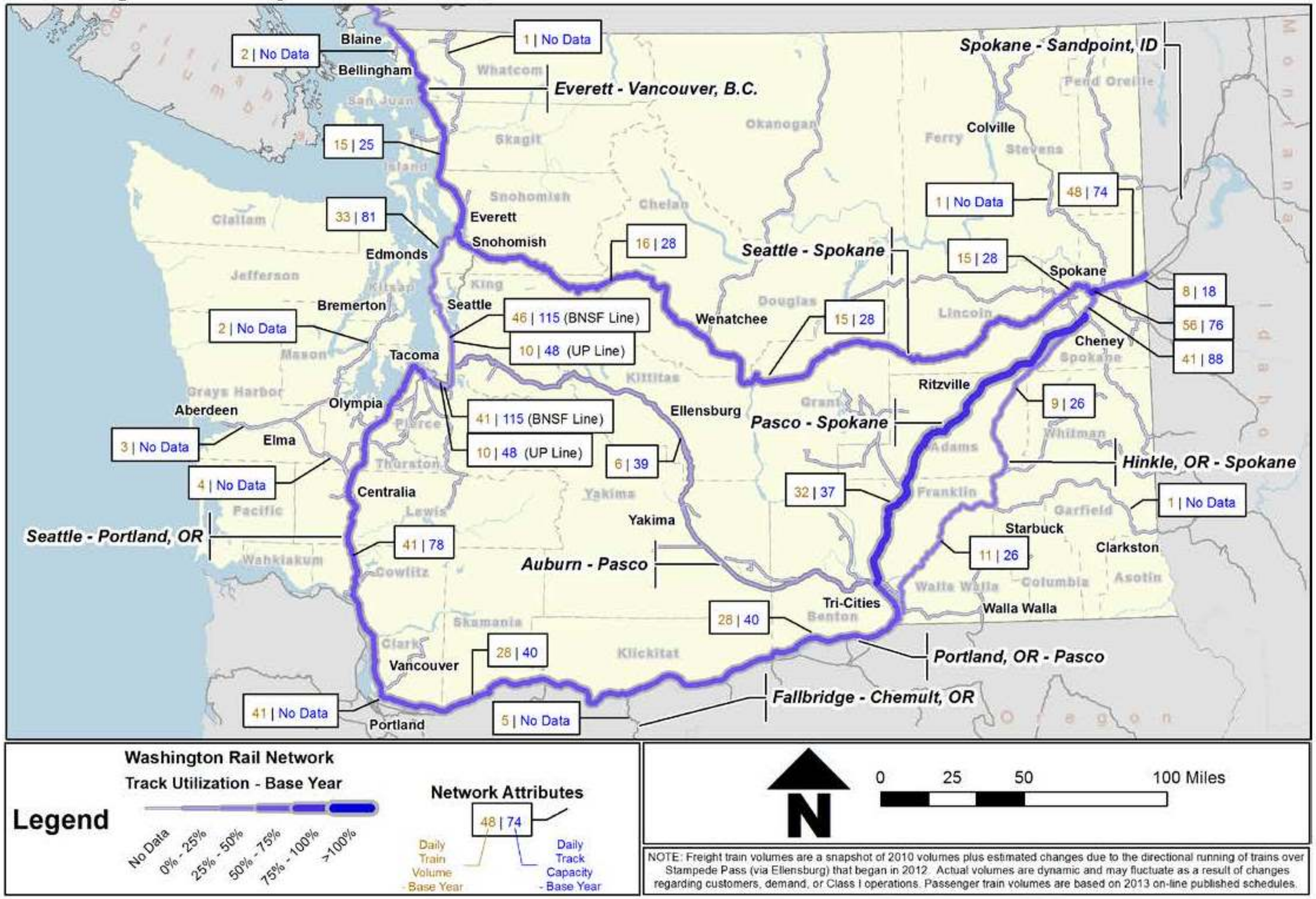
1. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco–City of Boise Solid Waste Strategic Plan (2007)
2. Columbia Ridge (www.wmnorthwest.com/landfill/columbiaridge.htm); Roosevelt–2013 Kickitat County SWMP Update; Finley Buttes–2015 Clark County Solid Waste Management Plan; Simco (www.epa.gov/lmop/project-and-landfill-data-state)
3. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco (estimated)
4. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco (www.epa.gov/lmop/project-and-landfill-data-state)
5. Cedar Hills Regional Landfill (CHRLF) 2028-2078 Solid Waste Tonnage Forecast (2016), KCSWD

Rail Capacity for Solid Waste Export

- Critical Segments
  - Tacoma to Kalama/Longview (137% capacity by 2028)
  - Kalama/Longview to Vancouver (143% capacity by 2028)
  - Vancouver, WA to Pasco (100% capacity by 2028)
  - Pasco to Spokane (100% capacity by 2028)
  - Spokane to Sandpoint, ID (100% capacity by 2028)

Washington State 2010-2030 Freight Rail Plan, 2009

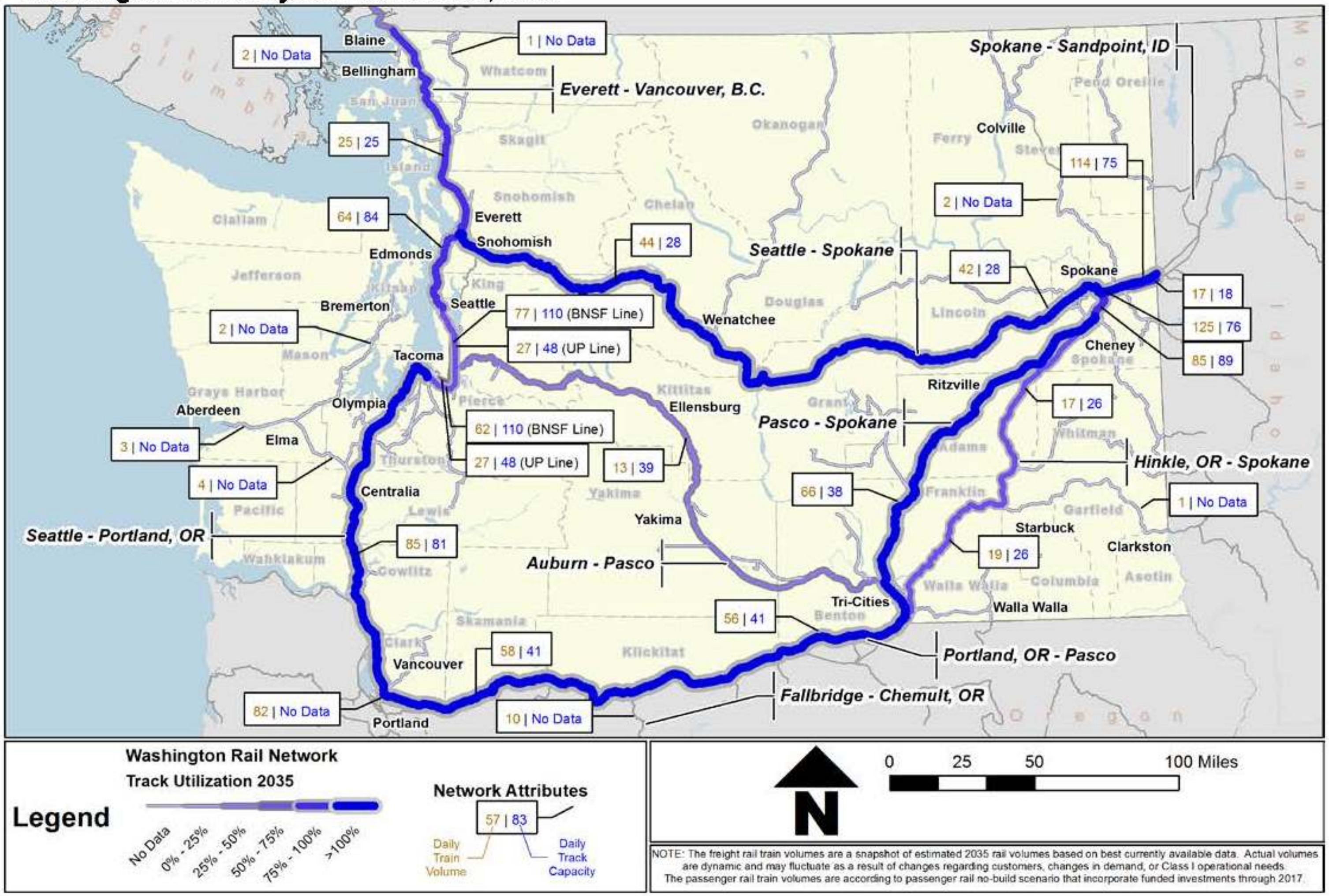
Figure 4.2 Washington's Rail System Utilization, 2010



Sources: 1) BNSF 2010 Train Counts Data for Washington; 2) UP 2012 Q1 Train Counts Data for Spokane-Eastport, Idaho corridor; and 3) Cambridge Systematics' Estimation of 2010 Train Volumes and Capacity Analysis using the 2011 BNSF Northwest Division timetable data, 2011 BNSF R-1 report data and a TransCAD Model of ORNL's Rail Network.

Note: Directional running of trains is assumed on the Stampede Pass route (Auburn-Pasco via Yakima), which was implemented by BNSF in 2012.

Figure 4.3 Washington's Rail System Utilization, 2035



Sources: 1) BNSF 2010 Train Counts Data for Washington; 2) UP 2012 Q1 Train Counts Data for Spokane-Eastport, Idaho corridor; and 3) Cambridge Systematics' Estimation of 2010 Train Volumes and Capacity Analysis using the 2011 BNSF Northwest Division timetable data, 2011 BNSF R-1 report data and a TransCAD Model of ORNL's Rail Network.

Note: Directional running of trains is assumed on the Stampede Pass route (Auburn-Pasco via Yakima), which was implemented by BNSF in 2012.

Recommendations

- § Consider Waste to Energy as a viable option for solid waste management in long range SWD plans
  - o The “Best Fit Technology” for King County is a thermal treatment system
    - Combustion on a movable grate with a waterwall boiler to recover heat for production of steam and electricity (massburn system)
    - Thermal recycling innovations and design features
- § Conduct a WTE Feasibility Study
- § Develop a Public Education Program

Feasibility Study Components

- “Best Fit” WTE overview including key recycling and disposal components of an Integrated Solid Waste Management System
  - Analysis of Existing Conditions to determine compatibility with a WTE-anchored system
  - Visit Palm Beach County, FL campus and other similar integrated solid waste management facilities
  - Comparative Analysis for cost effectiveness of integrated WTE system vs. out of county landfill

Feasibility Study Components

- Analysis of options for appropriately sizing WTE facility and ancillary treatment, recovery, recycling and disposal needs
  - Potential solid waste quantities and composition
  - Evaluate potential for treatments such as a stand alone anaerobic digestion facility and uses of bio-methane
  - Evaluate recycling technologies/processes and advanced material recovery options
  - Meet with other cities/counties for regional participation

Feasibility Study Components

- Design/Permitting/Construction Requirements
  - Analysis of environmental regulation and permitting process including criteria, permit requirements and potential schedule
- Siting and Architectural Options
  - Develop siting criteria, identify potential sites
  - Evaluate potential sites for WTE, ash monofill and bypass/backup disposal facilities and rank preliminary sites
  - Form architectural committee to evaluate design features

Feasibility Study Components

- Environmental Opportunities
  - Availability of fairly-priced energy, metals and materials markets
  - Evaluate integration of technologies for small amounts of bypass waste
- Economic Cost Assessment
  - Analysis of financial alternatives
  - Meet with local municipal and private utilities for interest in PPAs or financial participation in WTE project
- Conclusions, Recommendations and Implementation Plan
  - Key Tasks and Schedule for siting/design/build and key infrastructure systems

Next Steps – Public Education

- Develop public education approach
  - Identify committees and representation
- Identify and maintain a library of technical information, environmental data, architectural preferences, and public policies
- Identify type and schedule of public workshops
- Identify approach for maintaining historical project information (meeting agendas and minutes) and establishing methods for ensuring transparency

Questions?

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